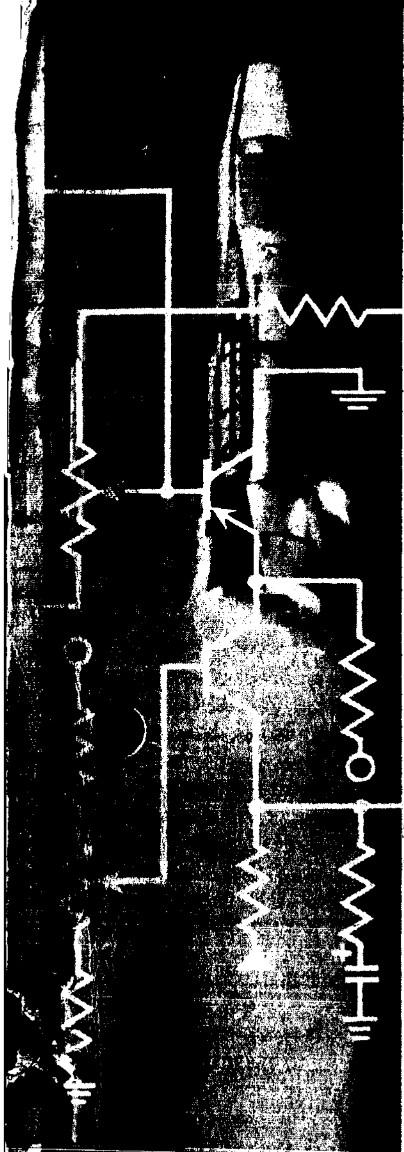
AFCRL-65-417



ELECTRONIC INSTRUMENTATION FOR IONOSPHERIC AND EXTREME ULTRAVIOLET RADIATION MEASUREMENTS

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CONTRACT No. AF 19(628)-2464

PROJECT No. 6688

TASK No. 668801, 02, 03, 04, 05, 06

Sponsored in part by NASA

under Project No. 6687

FINAL REPORT

1 MARCH 1965

Prepared

for

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS

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ABSTRACT

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This report describes the design, construction, test and flight use of the electronic portions of research instruments used on rockets and satellites for the investigation of ultraviolet solar radiation. These instruments include grating monochromators for measurements in the 55 - 1300 Angstrom range and proportional counter spectrometers in the 1 - 10 Angstrom range. Also described is work done on retarding potential analyzers used for analysis of environmental charged particles, including measurement of electron temperature. All the instruments are of a telemetering type. Associated equipment used for calibration and testing of the instruments in both the laboratory and the launch phases is described. Automatic data reduction equipment was developed and used successfully. Experiments involved OSO, OGO and Air Force satellites and Aerobee-150 and Black Brant rockets. author

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INTRODUCTION

The work performed under Contract AF 19(628)-2464 during 1963 and 1964 and described in this report is a continuation of the work begun by Adcole Corporation under Contract AF 19(604)-7391 during the years 1960 through 1962. The tasks assigned and successfully carried out can be broadly described as the design, construction, test and flight uses of electronic portions of research instruments used on rockets and satellites for the investigation of solar ultraviolet radiation.

The tasks are divided into several main categories as follows:

(1) The design, construction, test and flight of electronics for grazing incidence, scanning, telemetering, flight monochromators for measurement of the intensity of solar radiation in the 55 - 1300 Angstrom range. These instruments were for rocket vehicles and collected data for a short time over various altitudes.

(2) The design, construction, test and flight of electronics for grazing incidence, scanning, telemetering, flight monochromators for measurement of the intensity of solar radiation in the soft X-ray and extreme ultraviolet regions. These instruments are for satellite application and are light, take little power and have long life.

(3) The design, construction, test and flight of electronics for retarding potential analyzers for the analysis of environmental charged particles and electron temperature in the aerospace environment.

(4) The design, construction, test and flight of electronics for a proportional counter spectrometer for measuring X-ray radiation in the 1 - 10 Angstrom range.

(5) The design, development and construction of equipment to facilitate the reduction of the data obtained from the above instruments and to assist in the actual data reduction.

(6) Design, construction and use of laboratory and field test consoles for all the above instruments and also to assist in the installation and launching of the equipment at White Sands Missile Range.

All the above tasks are described in the following sections of this report, along with drawings and pictures. Only a small portion of the hundreds of drawings necessary for the completion of the tasks are shown.

LIST OF CONTRIBUTORS

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Adcole Corporation also acknowledges the very significant contributions of the following AFCRL personnel:

Hans E. Hinteregger
L. Alton Hall
Charles W. Chagnon
Werner Schweizer
Donald E. Bedo
James E. Manson

RELATED CONTRACTS AND PUBLICATIONS

Related Contracts:

"Investigation of Ultraviolet Solar Radiation," Comstock and Wescott, Contract No. AF 19(604)-7496

"Instrumentation for Rocket Probe Ionospheric and Extreme Ultraviolet Solar Radiation Measurement," Adcole Corporation, Contract No. AF 19(604)-7391

Related Publications:

Bedo, D.E. and H.E. Hinteregger, "Collimator Grating Monochromators for the Vacuum Ultraviolet," Presented at Conf. on Photographic and Spectroscopic Optics, Tokyo, 1-8 Sept. (1964). Jap. J. Appl. Phys, May (1965)

Hall, L.A., W. Schweizer and H.E. Hinteregger, "Diurnal Variation of Atmosphere Around 190 Km. from Solar EUV Absorption Measurements," J.G.R. 68, 6413 (1963)

Hall, L.A., W. Schweizer and H.E. Hinteregger, "Improved Extreme Ultraviolet Absorption Measurements in the Upper Atmosphere," J. Geophys. Res. 70, 105-111 (1965)

Hall, L.A., W. Schweizer, L. Heroux and H.E. Hinteregger, "Solar XUV Spectrum of March 1964," Astrophys. J. (1965)

Heroux, L., J.E. Manson and R. Smith, "Proportional Counter Spectrometer for Solar X Rays between 1 and 10 Angstroms," Instr. for Geophys. & Astrophys. No. 23, AFCRL 62-1105 (1962)

Heroux, L., J.E. Manson, H.E. Hinteregger and W.J. McMahon (C&W), "Photoelectric Yields for Oblique Incidence of Extreme Ultraviolet Radiation," J. Opt. Soc. Am. 55, 103 (1965)

Hinteregger, H. E., "Absorption Spectrometric Analysis of the Upper Atmosphere in the EUV Region," J. Atm. Sci. 19, 351-368 (1962)

Hinteregger, H.E., "Photoelectric Spectrophotometry of Solar Extreme Ultraviolet Radiation," J. Quant. Spectrosc. Radiat. Transfer 2, 561-569 (1962)

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Manson, J.E., "Solar X Rays from 3 to 12 Angstroms as Measured with a Proportional Counter Spectrometer," AFCRL Research Rpt. No. 64-932 (1964)

1. ROCKET MONOCHROMATORS

CONTENTS

1. ROCKET MONOCHROMATOR

1.1 Introduction

The work performed under this contract, AF 19(628)-2464, is a continuation of the work carried out on a previous contract, AF 19(624)-7391, which ran from July 1960 through December 1962. Under that contract, electronic systems were developed which became part of the EUV telemetering monochromator. The present contract work continued the development of improved electronics and scanning drive methods and the firing of five monochromators from White Sands, New Mexico.

1.2 Description of the EUV Telemetering Monochromator and Its Electronic System

The telemetering EUV monochromator is a grazing-incidence grating monochromator using a photoelectric detector to produce electrical impulses which are telemetered to the ground during flight rather than using a film pack which must be recovered in order to obtain the data. A picture of the instrument is shown in Figure 1.1. To obtain measurements of the intensity of radiation of various wavelengths at various atmospheric altitudes, the instrument is mounted on a solar pointing control on the nose of an Aerobee-150 rocket and fired to altitudes of approximately 150 miles.

A schematic layout of the instrument is shown in Figure 1.2. A block diagram of the electronic system is shown in Figure 1.3.

1.2.1 Detector

Photons, of a wavelength selected by the slit in the scanning belt, impinge on the detector cathode, producing photoelectrons. The photoelectrons are multiplied in the multiplier section of the photomultiplier so that at the output of the photomultiplier a pulse of current is produced for each photoelectron that enters the multiplier section. These current pulses are amplified and used to fire two independent binary chains. Thirty-two step staircase outputs from three sets of five binary stages are telemetered to the ground. By counting the steps as produced in analog form on the telemetry paper, the photons per second (or intensity) of each wavelength in the scanned spectrum can be determined, since the instantaneous wavelength position of the scanning slit is also telemetered simultaneously on another telemetry channel.

The photomultiplier requires several high and low voltages for its operation. These are derived from a single high voltage power supply which feeds a zener diode chain to produce the necessary voltages. Each photomultiplier requires slightly different voltages and the zener diodes must be individually selected to give these voltage. However, once selected, these voltages are stable because of the zener action and in addition, the high voltage supply itself is well regulated. The high voltage power supply, zener diode card and pulse preamplifier are contained in a pressurized aluminum box to eliminate any possible troubles from high voltage corona, arcing or outgassing from the power supply. A picture of the high voltage assembly is shown in Figure 1.4.

1.2.2 Pulse Amp

The pulse amplifier must amplify very short low current pulses to trigger the binary counters. It operates over a large dynamic range and to a pulse rate of several megacycles. Schematics are shown in Figures 1.5 and 1.6.

1.2.3 Binary Counters

The binary stages are of two types. The ones immediately following the pulse amplifier are made to operate at high frequency while the ones at the end of the binary chain are simpler, since a high rate of operation is not required. On the initial instruments, the output consisted of staircases made from groups of five binaries. A staircase was chosen because at low counting rates each step is resolvable, but at high rates, when the individual steps are lost because of inadequate telemetry bandwidth, the complete staircase ramps are still readable. Thus the dynamic frequency range of the telemetry channel is greatly increased. Even with this technique, at least two channels have been required to get enough dynamic range to measure the great spread of solar intensities. Schematics are shown in Figure 1.7 and 1.8. A photograph of the electronic assembly is shown in Figure 1.9.

1.2.4 Scanning Drive

The early monochromator scanning belt was driven by a d-c motor powered from the instrument batteries. As battery voltage dropped during flight, motor speed was not constant, making data reduction difficult. To correct this condition a synchronous motor drive is now used. The motor is driven by a square wave of constant frequency generated electronically by special circuitry developed by Adcole Corporation. A schematic is given in Figure 1.10 and a photograph in Figure 1.11.

1.2.5 Wavelength Readout

The wavelength position of the exit scanning slit in the moving belt is telemetered to the ground simultaneously with intensity data. On early monochromators, with the d-c motor, contacts on the drive shaft, similar to a commutator, produced pulses which were counted to determine exact wavelength position. This arrangement gave trouble because of contact wear. When the change was made to a synchronous motor, a different position indicator was developed. The existing sprocket holes in the belt are used to allow light from a lamp to reach a photoconductive cell and produce a pulse from an electronic circuit. An extra hole in the belt is used to indicate the beginning of each scan. By using three cells a total of 54 pulses are produced during each scan of the belt which has 18 holes. This system has performed well. A picture of the optical assembly including the electronics is shown in Figure 1.12.

1.2.6 Commutator

A commutator is used to time share on one telemetry channel auxiliary information on the performance of the equipment. This commutator is made by Adcole Corporation. It is a solid state switching device presenting its output in IRIG form so that automatic decommutation can be performed if desired. The commutated data consists of monitor voltages from both low voltage and high voltage power supplies, battery voltage, and output data from piggyback experiments. A schematic is shown in Figure 1.13 and a photograph in Figure 1.14.

1.3 Modifications - The Aeronomical Model

The so-called "general purpose" monochromator was modified to provide EUV absorption data having greater aeronomical significance. The modification consists of replacing the moving exit slit by nine fixed slits which are opened singly in turn by solenoid operated shutters. These fixed slits are positioned at nine pre-selected wavelengths. In this way much more information may be obtained about these wavelengths than would be possible with the scanning slit, which spends most of its scan time looking at wavelengths of little interest.

To actuate the shutters an electronic unit was developed to open each shutter in turn for 1/3 of a second and then leave-all shutters closed for 1/3 of a second so that background count can be measured before opening the first shutter again. This circuitry was built and installed on the monochromator casting in the same box that formerly held the motor drive unit which, of course, is not used with the shutters. A photograph and schematic are shown in Figures 1.15 and 1.16.

1.4 Spectral Calibration of the Monochromator

The method used for calibration of the flight monochromator using a high intensity light source is given in Figure 1.2. The monochromator is placed in a vacuum chamber that is part of the exit structure of a laboratory monochromator. The input aperture is adjusted to the same angle that the sun subtends in flight by means of an aperture limiter. A tungsten reference detector is moved into the light path between the entrance slit and the grating so that all monochromatic radiation striking the grating is intercepted by the detector. For each wavelength used for calibration the output counting rate from the monochromator electronics is compared to the photoelectronic saturation current of the tungsten reference detector when it is inserted into the light path.

Consoles, test pulse generators and wiring for operation of the monochromator in the vacuum tank were developed by Adcole Corporation.

For calibration at short wavelengths where the only light sources available are of low intensity, a different method of calibration is used. A small photomultiplier of the same type as the instrument photomultiplier is placed in the light path instead of the tungsten detector. The photomultiplier has great sensitivity and is usable with the low intensity sources. The photomultiplier is connected to a high voltage power supply and zener diode card and its output is fed to a pulse amplifier and counter just as is the main photomultiplier in the instrument. This equipment is also built by Adcole Corporation. The calibration photomultiplier system is calibrated against the tungsten reference detector at long wavelengths and high intensity and its count rate at low intensity and short wavelengths is directly proportioned. The counts from the calibration photomultiplier are compared to the counts from the monochromator to give calibration figures for short wavelengths where the light sources are of low intensity.

1.5 Chronology

Table 1.1 is a chronological listing of flight experiments performed with the Rocket Monochromator during this contract.

TABLE 1.1 - ROCKET MONOCHROMATORS

INSTRUMENT	EXPERIMENT	VEHICLE	LOCATION	REMARKS
RM-17	Measure EUV radiation 325 - 62 Å range	Aerobee 150	WSMR New Mexico	Launched 2 May 1963. Successful launching. Good results obtained.
RM-18	Measure EUV radiation at nine fixed wavelengths	Aerobee 150	WSMR New Mexico	Launched 10 July 1963. Successful launching. Good results obtained.
RM-19	Measure EUV radiation 1300 - 250 Å range	Aerobee 150	WSMR New Mexico	Launched 12 December 1963. Successful launching. Good data.
RM-20	Measure EUV radiation at nine fixed wavelengths	Aerobee 150		Launched 3 March 1965. Good data.
RM-21	Measure EUV radiation at nine fixed wavelengths	Aerobee 150		Scheduled Second Quarter 1965
RM-22	Measure EUV radiation 310 - 55 Å range	Aerobee 150	WSMR New Mexico	Launched 30 March 1964. Experiment successful. Good results obtained.
RM-23	Laboratory Investigations		AFCRL Laboratory	
RM-24	Measure EUV radiation Short wavelength range			Scheduled 1965
RM-25	Measure EUV radiation at nine fixed wavelengths	Aerobee 150	WSMR New Mexico	Launched 8 December 1964. Successful launching. No data. Electronics performed satisfactorily but either no light reached photomultiplier or multiplier produced no pulses at input to pulse amplifier.

1.6 Flight Operations

The following is a description of the field operations associated with the launching of each rocket instrument. After final calibration, the assembly of each instrument is completed and another electrical bench check is made. Also a telemetry radiation interference check is made using a telemetry transmitter similar to the one which will eventually be used with the instrument on the rocket. The instrument is then hand carried to Ball Brothers Research Corporation, Boulder, Colorado, for integration with the solar pointing control in the nose of the rocket.

The integration consists of mechanical installation of the instrument on the pointing control, fastening the pointing control eye block and wires to the instrument, operating the instrument in conjunction with the pointing control through the pointing control wiring harness and pull-away system. The telemetry equipment is installed and simulated data transmitted to a local ground station. A pointing control performance check is made by running through a complete launch sequence. The rocket nose is spun up on a rotating table, azimuth pointing accomplished, nose ejected, instrument released, elevation pointing accomplished, and instrument high voltage activated. The telemetry is in operation so a complete paper record is obtained of all monitor voltages and simulated data. A photograph of the instrument on the pointing control is given in Figure 1.1.

Before shipment to White Sands, New Mexico for launch, Comstock and Wescott personnel perform vacuum pumping tests on the nose to insure absence of leaks since prior to launch the instrument compartment is evacuated to clean the instrument and insure rapid pump out during flight.

Power for the instrument during flights is the responsibility of Adcole Corporation. Initially nickel cadmium batteries were used, but when trouble was encountered with electrolyte leakage a change was made to silver zinc cells. These cells do not generate internal pressure when charging and hence leakage is more easily controlled. Also they are lighter and small for a given capacity. The battery is shown in Figure 1.17. Nineteen cells are used, giving one ampere hour at 28.5 volts.

Figure 1.18 shows a console built for use during bench checks and in the blockhouse to operate the instrument prior to launch. It monitors input power, instrument voltages and signals, produces test pulses, manually steps the commutator and controls battery charge and predischarge necessary before launch. The schematic is shown in Figure 1.19.

At White Sands the instrument is rechecked and the complete payload assembly attached to the rocket body for indoor horizontal checks. It is determined at this time that no electrical interference exists between the instrument, pointing control, telemetry, beacon transponder and range safety receiver.

The payload is then removed from the rocket the rocket installed in the Aerobee tower and the payload reinstalled. Land lines are checked, pull-aways connected and consoles set up in the blockhouse. A pointing control and instrument check is then made using launch procedure again.

If this check is satisfactory, the payload assembly is buttoned up for launch. Vacuum pumping is accomplished by Comstock and Wescott personnel immediately prior to launch and instrument performance is monitored at the console until pull-aways are disengaged at lift-off. The above described procedure for each instrument firing requires at least one Adcole man at Ball Brothers Research Corporation for a week and at least two Adcole men at White Sands for almost two weeks if no delays are encountered.

A description of each instrument and flight data is given below.

RM #17 2 May 1963

Rocket Monochromator #17 was launched at White Sands Missile Range, New Mexico at 10:03 MST 2 May 1963 on Aerobee-150 vehicle. Correct rocket behavior was obtained, the solar pointing control performed well and the experiment operated as planned.

The monochromator scanned the short ultra-violet wavelengths from 60 to 325 Angstroms. The scanning belt moved relatively slowly, requiring 100 seconds for a complete scan. Three scans were obtained. The short wavelength data obtained were the first of this wavelength since January 1960.

A silver zinc battery was used to power the experiment for the first time. The battery performed well, maintaining a more constant voltage than the previous nickel cadmium battery.

The monochromator casting also carried two secondary experiments, a proportional counter giving information in the 1 to 10 Angstrom range and a re-tarding potential analyzer. These experiments are reported in a later section of this report.

RM #18 10 July 1963

Rocket Monochromator #18 was launched at White Sands Missile Range, New Mexico at 10:02

MST 10 July 1963 on an Aerobee-150 vehicle. This instrument was the first of the fixed wavelength "Aeronomical" monochromators. The rocket and pointing control performed correctly. The instrument with its new arrangement to examine nine different wavelengths gave good data in the 250 to 1300 Angstrom region. Each wavelength was viewed for about one-third of a second which, with a dead time for background count, gave a three-second total scan time.

This instrument was the prototype of the instrument to be used in the Geoprobe Program.

The data was reduced by automatic reduction techniques developed by Adcole Corporation. This work is reported in the next section.

The instrument carried a retarding potential analyzer for electron temperature measurements. This failed to function due to an apparent "OPEN" in the detector.

RM #19 12 December 1963

Rocket Monochromator #19 successfully measured data in the 250 to 1300 Angstrom range with better resolution than previously obtained. A slow scan of 30 seconds in duration was used in conjunction with narrow entrance and exit slits. The data was reduced by automatic techniques with the aid of equipment developed and built by Adcole Corporation.

The instrument was launched from White Sands Missile Range, New Mexico at 11:50 MST on 12 December 1963. The shot had been originally scheduled for launch in October but continuous solar flare activity forced postponement.

The instrument also carried a proportional counter in the 1 to 10 Angstrom range and a retarding potential analyzer.

RM #22 30 March 1964

Rocket Monochromator #22 was successfully launched at noon on 30 March 1964 from White Sands, New Mexico. This instrument measured radiation in the short wavelength region (55 - 310 Å) previously monitored by RM #17. This time an even slower scan lasting 200 seconds was used. Since the total data collecting time is less than 300 seconds the scan was programmed to start at the region of interest when the high voltage was energized at +150 seconds. Excellent data were obtained from the monochromator and also from the retarding potential analyzer.

RM #25 8 December 1964

Rocket Monochromator #25, a fixed wavelength model similar to #18, was launched at White Sands 8 December 1961. This instrument was meant to take the first of two measurements, one in the afternoon with low sun angle, and the other the following morning at the same sun angle to determine diurnal variations.

To increase the chances of success, four instruments were prepared, RM #20, RM #25, RM #26 and RM #27. Instruments #25, #26 and #27 were integrated with pointing controls, and three rockets were readied at White Sands. RM #20 was kept as a spare. The plan was that if the first instrument was successful in the afternoon, a second instrument would be fired the next morning. If this was also successful, the mission would be complete. If the second instrument did not operate correctly, the third instrument would be fired the next day, with the spare instrument package available if the third instrument failed before launch.

However, if the first firing was not successful, the experiment would be postponed since it was thought to be not feasible to expect two good flights in a row after one failure.

The three instruments were mated with their respective pointing controls and the spare unit was checked with two of them.

In December 1964, horizontal checks of the three complete systems were made at White Sands. Instrument #25 was checked in the tower and fired the afternoon of 8 December. Although all instrument monitors indicated correct operation, no data was obtained. Analysis has not provided any definite answer as to what happened, but indications are that either the radiation did not reach the grating and detector or detector output did not reach the electronics. The remaining instruments were returned to AFCRL for use at a future date.

In additi on to the instruments mentioned above several other instruments were prepared. RM #21 was prepared for future use. RM #23 was incorporated in a laboratory set up for research at short wavelengths. RM #24 is being held for use when this research is completed.

This laboratory work has required some special electronics and motor-drive units which have been built by Adcole Corporation.

1.7 Data Reduction

A program for semi-automatic reduction of the data from the rocket monochromator instruments has been carried on by Adcole Corporation. Two different approaches have been followed, one for the continuously scanning monochromator and one for the aeronomical model which looks at nine different wavelengths.

1.7.1 Data Reduction of the Scanning Monochromator

The manual process for obtaining a plot of intensity versus wavelength is as follows: The telemetry paper records at either 10 inches per second or 40 inches per second. The staircase outputs of the high speed counter are divided into 5 or 10 millisecond intervals. The number of steps in each interval is counted and tabulated. On a 250-second data record from one flight, this means counting and tabulating 50,000 points if complete data is required at all wavelengths. In addition, three or five point averaging is desirable. Then the final points must be plotted.

Electronic circuits to accomplish the same operations have been developed and packaged in a Data Reducer Console, shown in Figure 1.20. A block diagram is given in Figure 1.21.

Magnetic tape of the composite subcarrier telemetry signals is played back at Northeastern University and the signal from the 70 kilocycle channel is recorded on another tape. This intermediate tape is then used to drive the data reducer console. The staircases are first differentiated, then used to produce trigger pulses which are gated alternately to two 7-stage binary counters. The analog output voltages from the counters are gated together again, smoothed and applied to a Sandborn recorder. This arrangement, shown in Figure 1.22, produces a plot of intensity versus wavelength. After the set up is completed and calibrated, data from one rocket shot can be reduced at the real-time rate or approximately 5 minutes per shot. The data obtained by RM #19 was reduced in this manner. Very strong solar lines are beyond the dynamic range of the high-speed channel. These lines are reduced by hand using paper records of the lower-speed channel.

1.7.2 Data Reduction of the Aeronomical Monochromator

Since the Aeronomical Monochromator measures intensity of the solar radiation at only nine preselected wavelengths, the data reduction process is different and yields data in different form. The final form desired is a listing or plot of the intensity at each separate wavelength versus altitude. Each wavelength is monitored in turn for about one-third of a second so there are only about 750 points to be counted and tabulated.

This is done automatically as follows: An intermediate tape is made containing four tracks. Three are used for data counted down at three different ratios and the fourth contains a wavelength signal. This wavelength signal is used to generate start-stop pulses which control the counting time of a decade counter which is fed by data from one of the other tape channels. The start-stop pulses enable the counter for exactly one-quarter of a second in the center of the one-third of a second counting interval at each wavelength. The counter is connected to a printer which prints the count accumulated during each wavelength readout. The tape must be run three times to produce a print record for each of the three different data channels and a composite tabulation made using the appropriate data channel for the different intensities.

The above system was used to successfully reduce the data from RM #18 and will be used on future aeronomical monochromators.

1.8 List of Figures

Figure

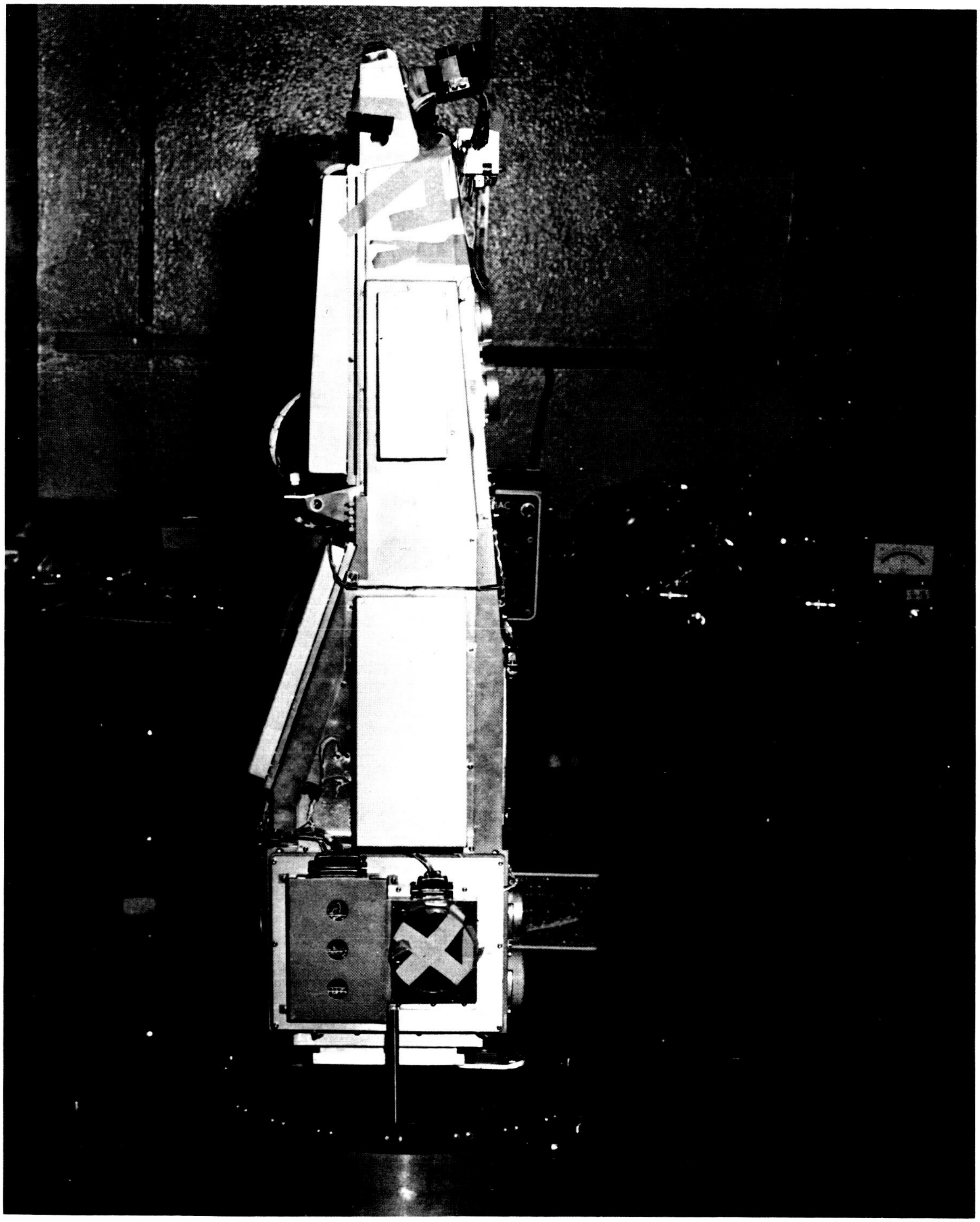

Figure 1.1 EUV Monochromator

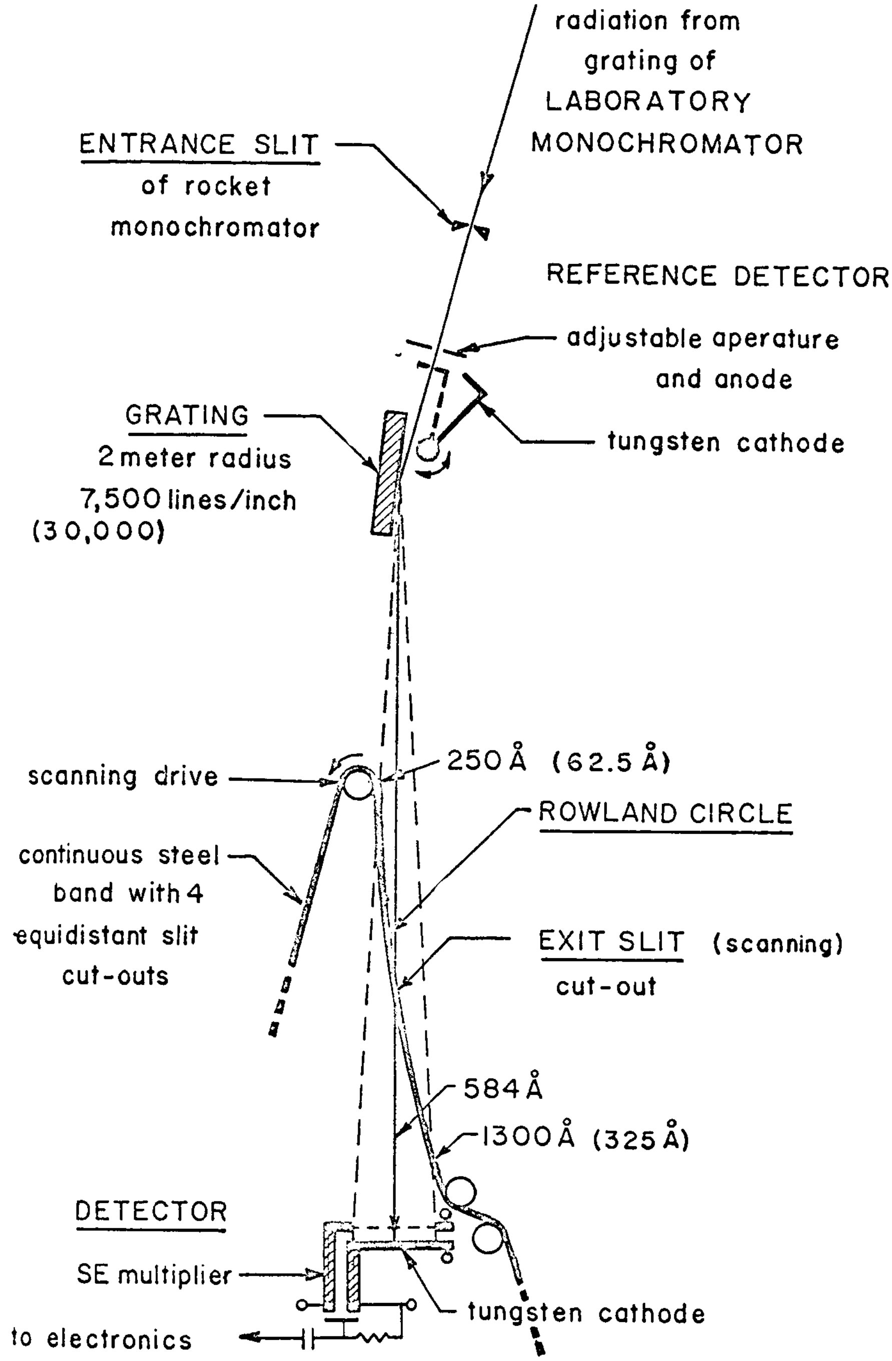

Figure 1.2 Pictorial Layout of EUV Monochromator

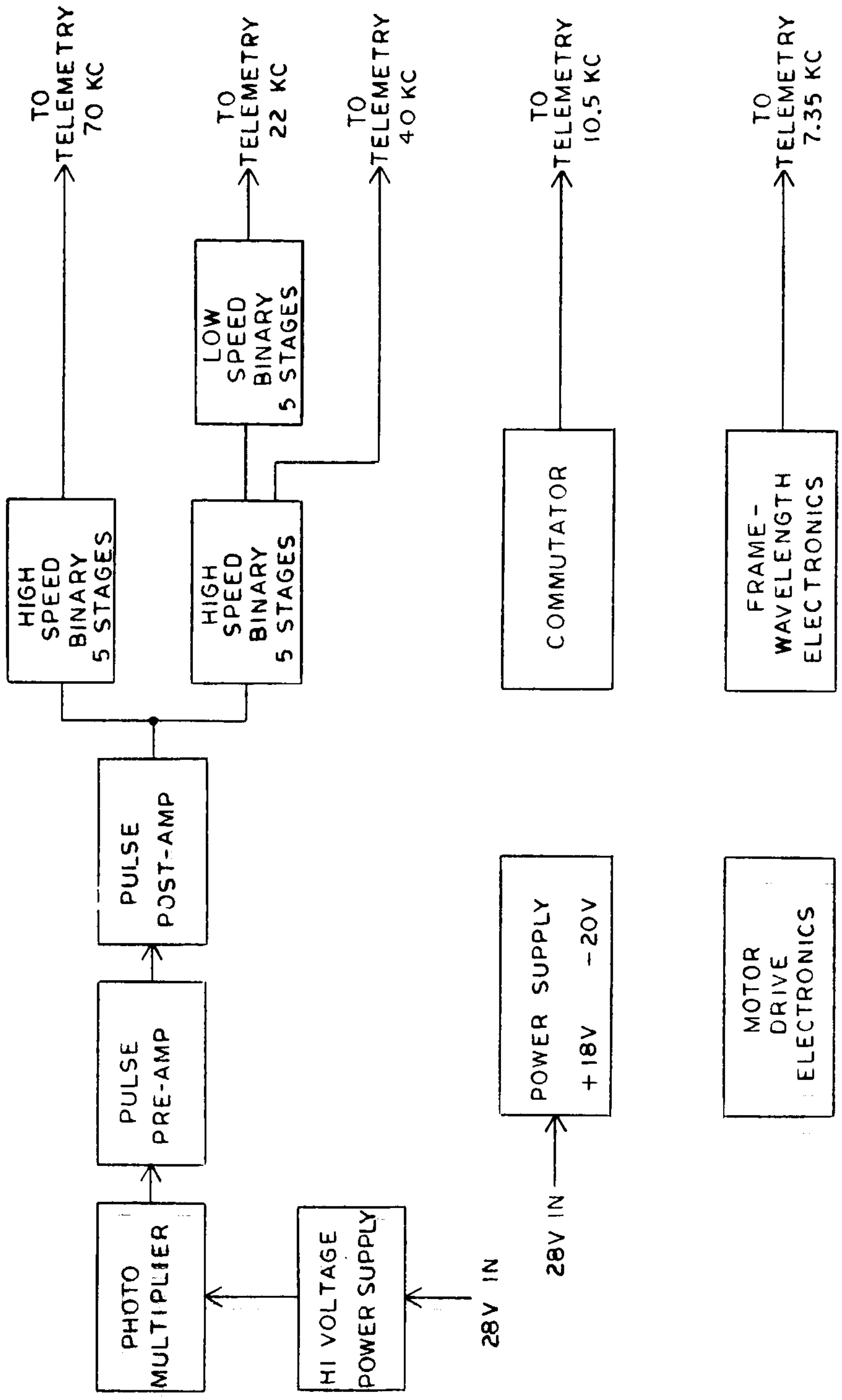

Figure 1.3 Block Diagram - Monochromator Electronics

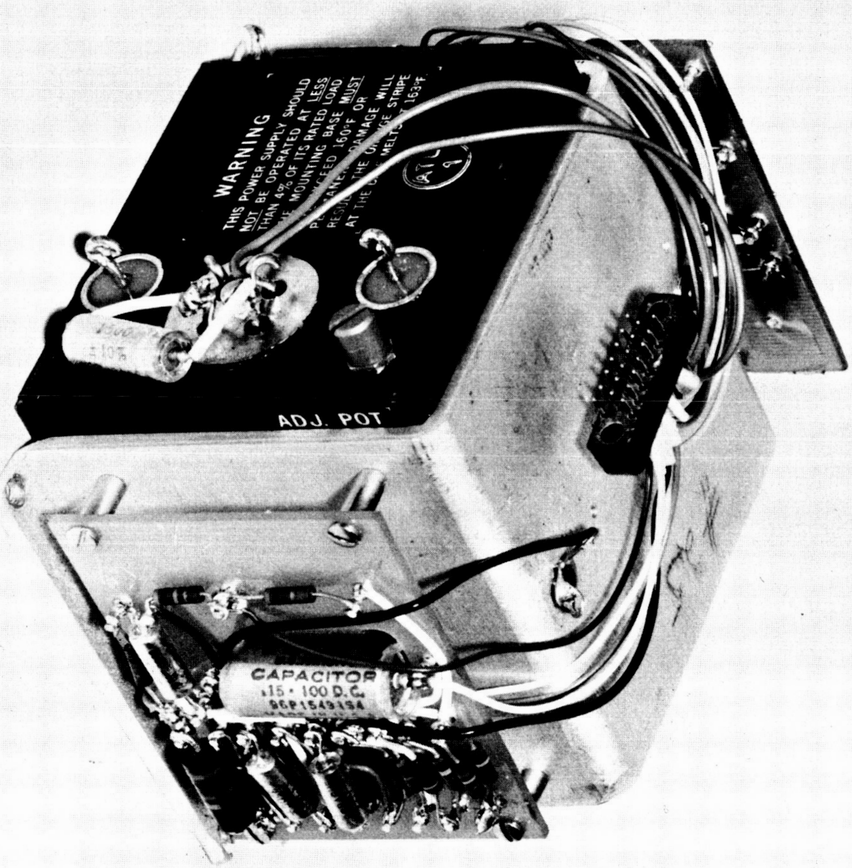

Figure 1.4 High Voltage Assembly - Monochromator

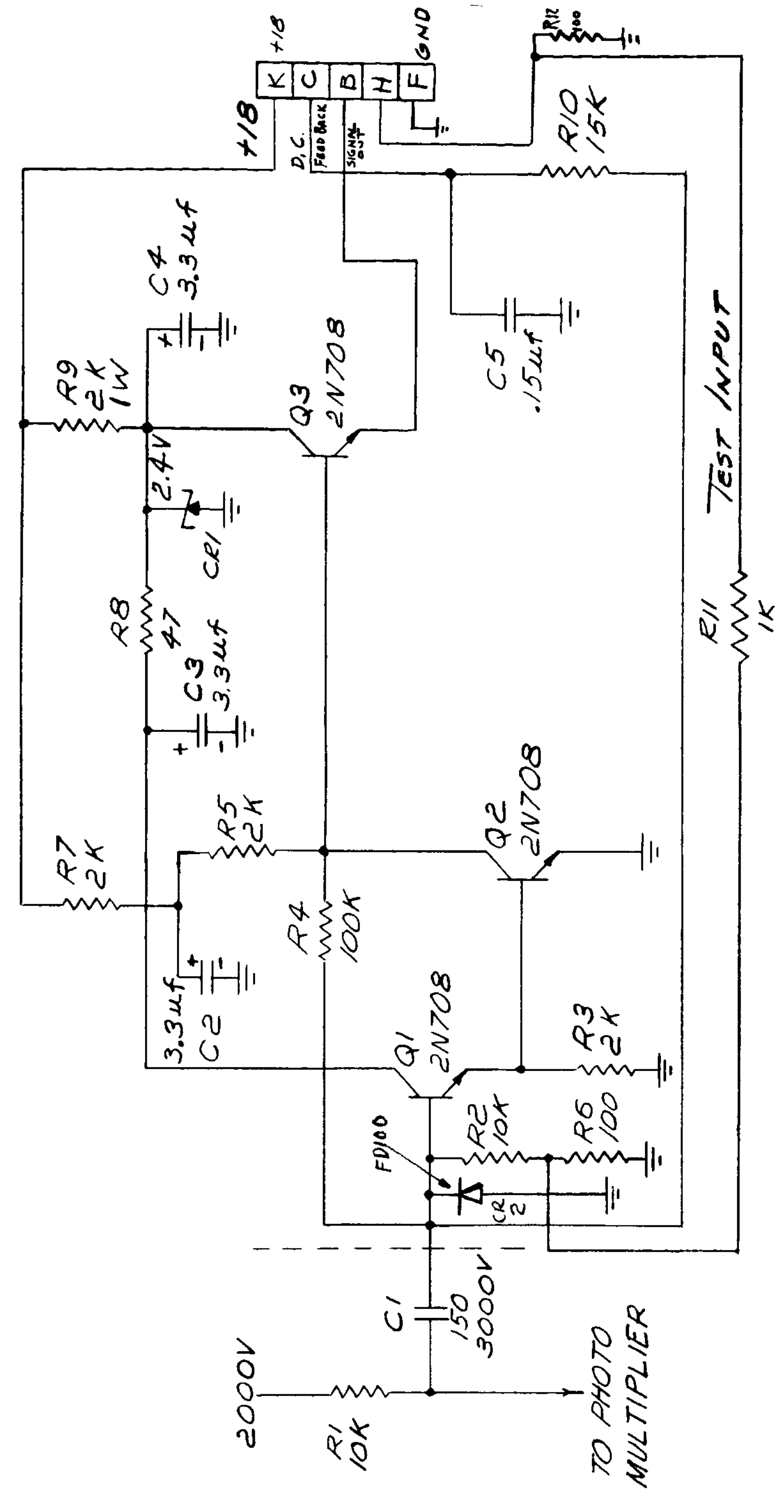

Figure 1.5 Monochromator Pulse Pre-Amplifier

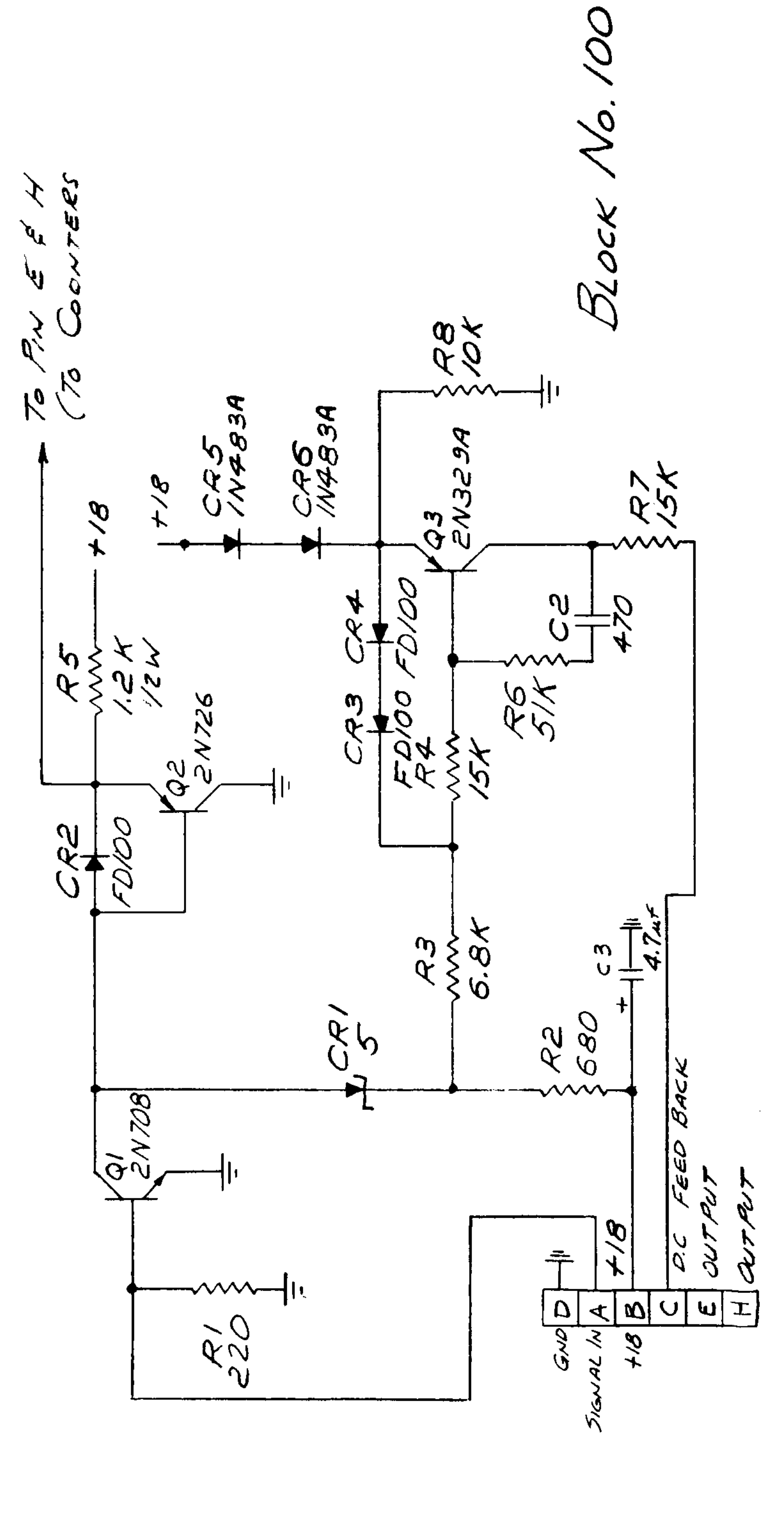

Figure 1.6 Monochromator Pulse Post-Amplifier

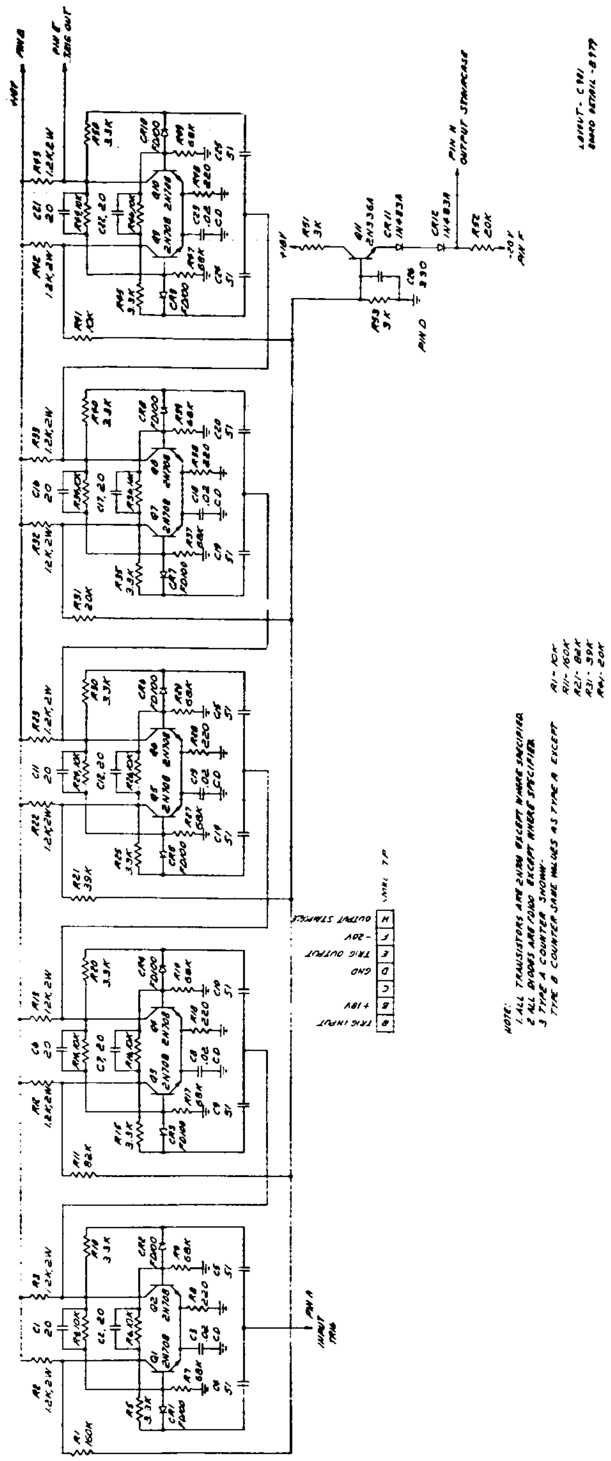

Figure 1.7 Schematic - High Speed Counter Type A, High Speed Counter Type B - Monochromator

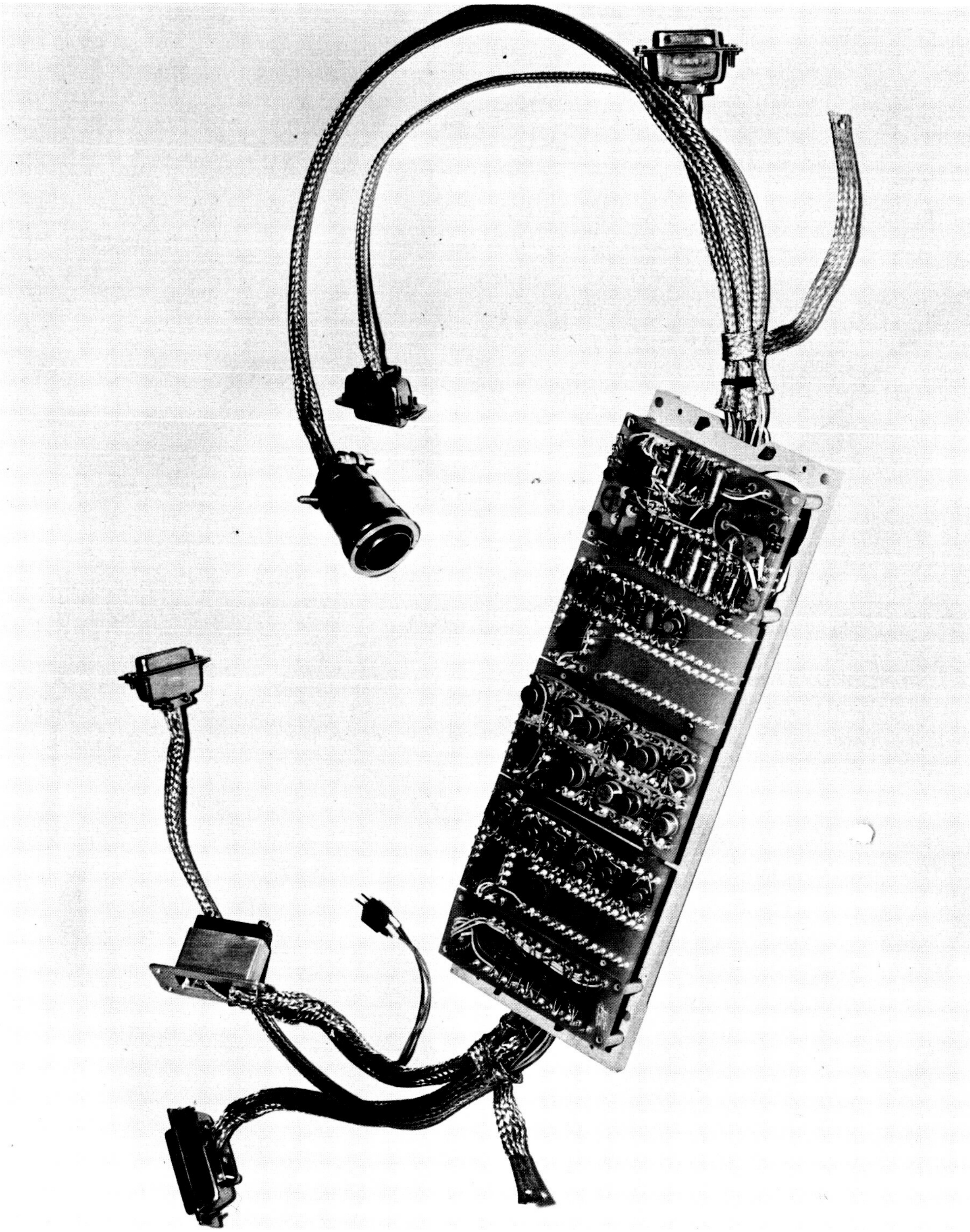

Figure 1.9 Monochromator Electronic Assembly

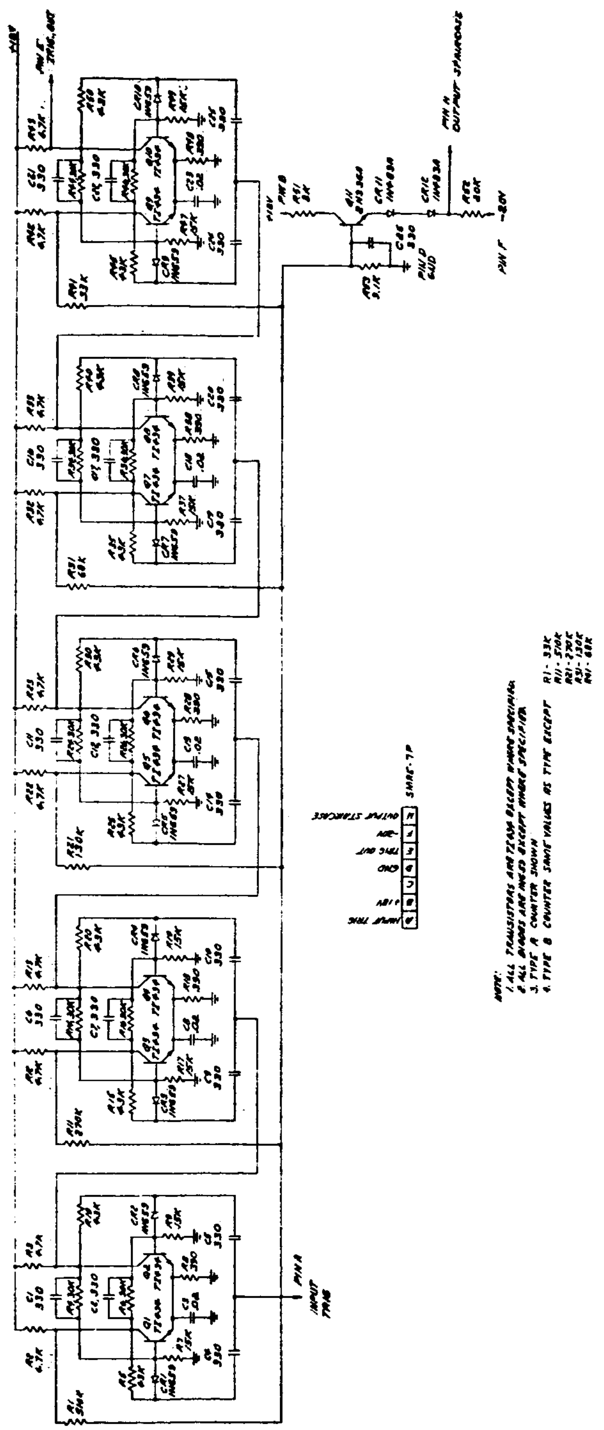

Figure 1.8 Schematic - Low Speed Counter-Monochromator

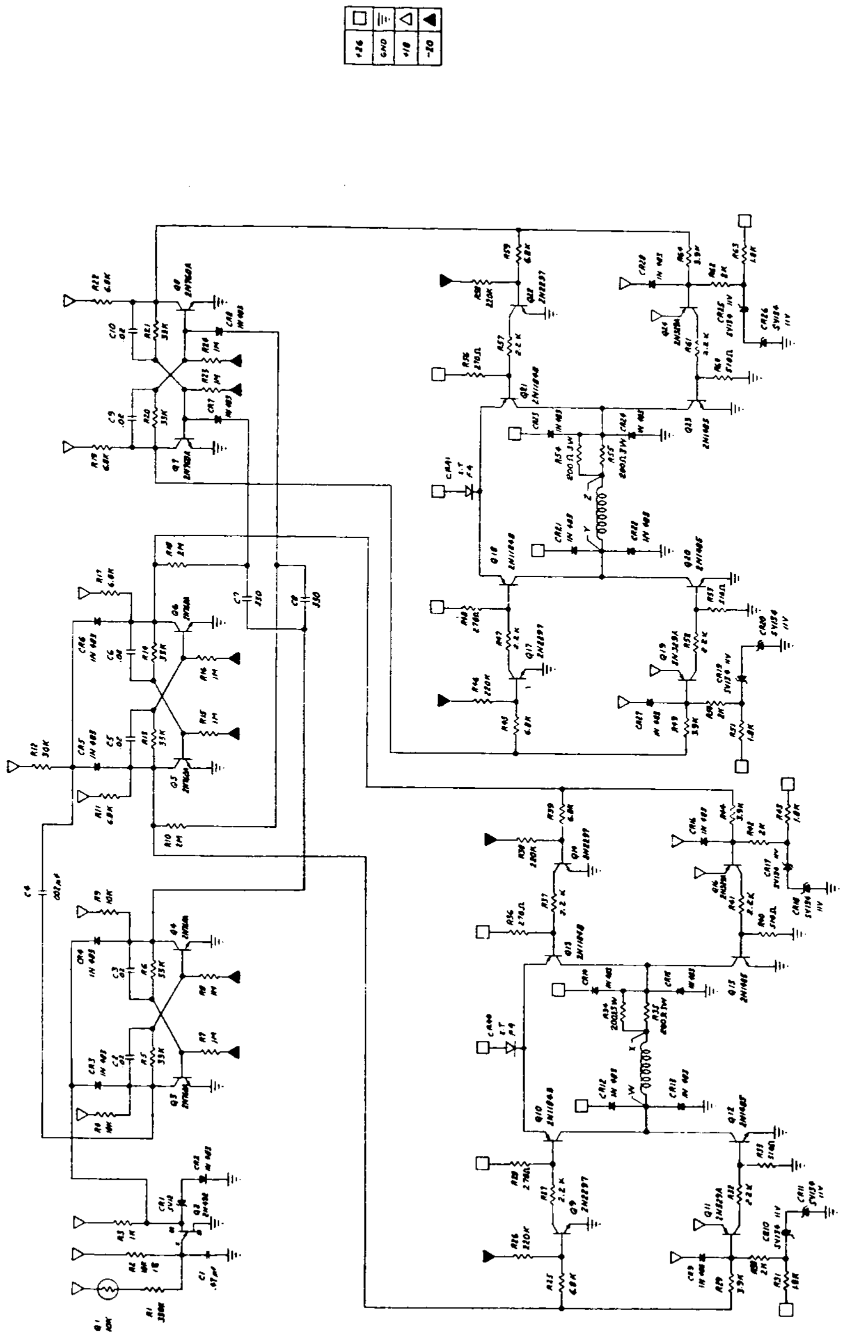

Figure 1.10 Schematic - Synchronous Motor Drive - Monochromator

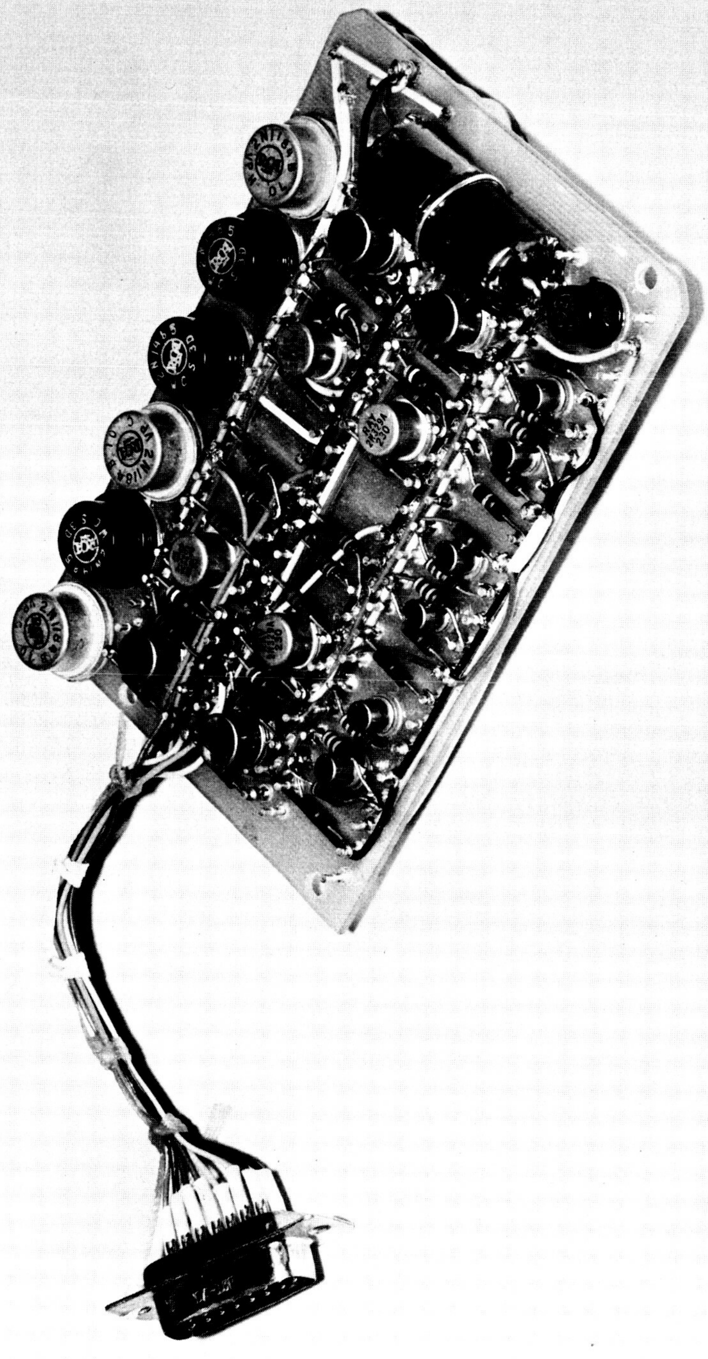

Figure 1.11 Synchronous Motor Drive - Monochromator

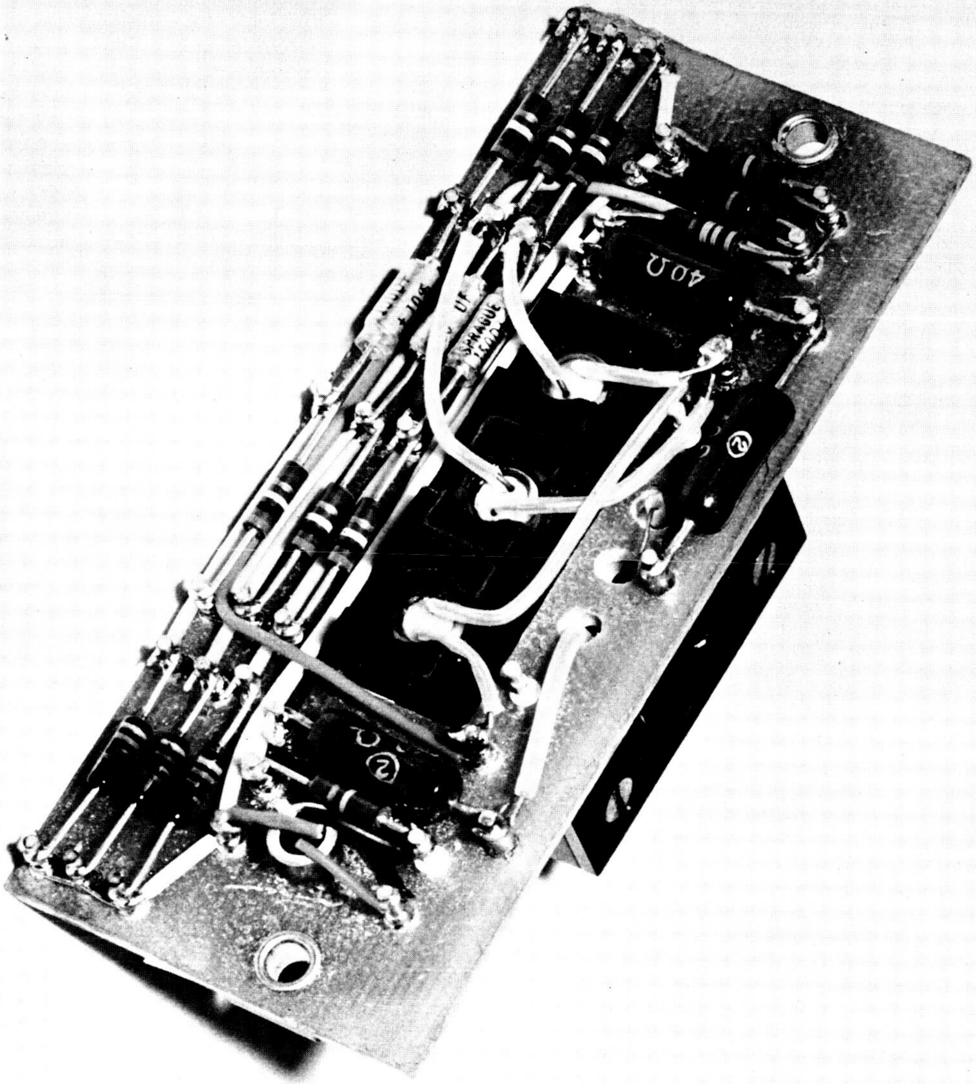

Figure 1.12 Frame and Wavelength Assembly -
Monochromator

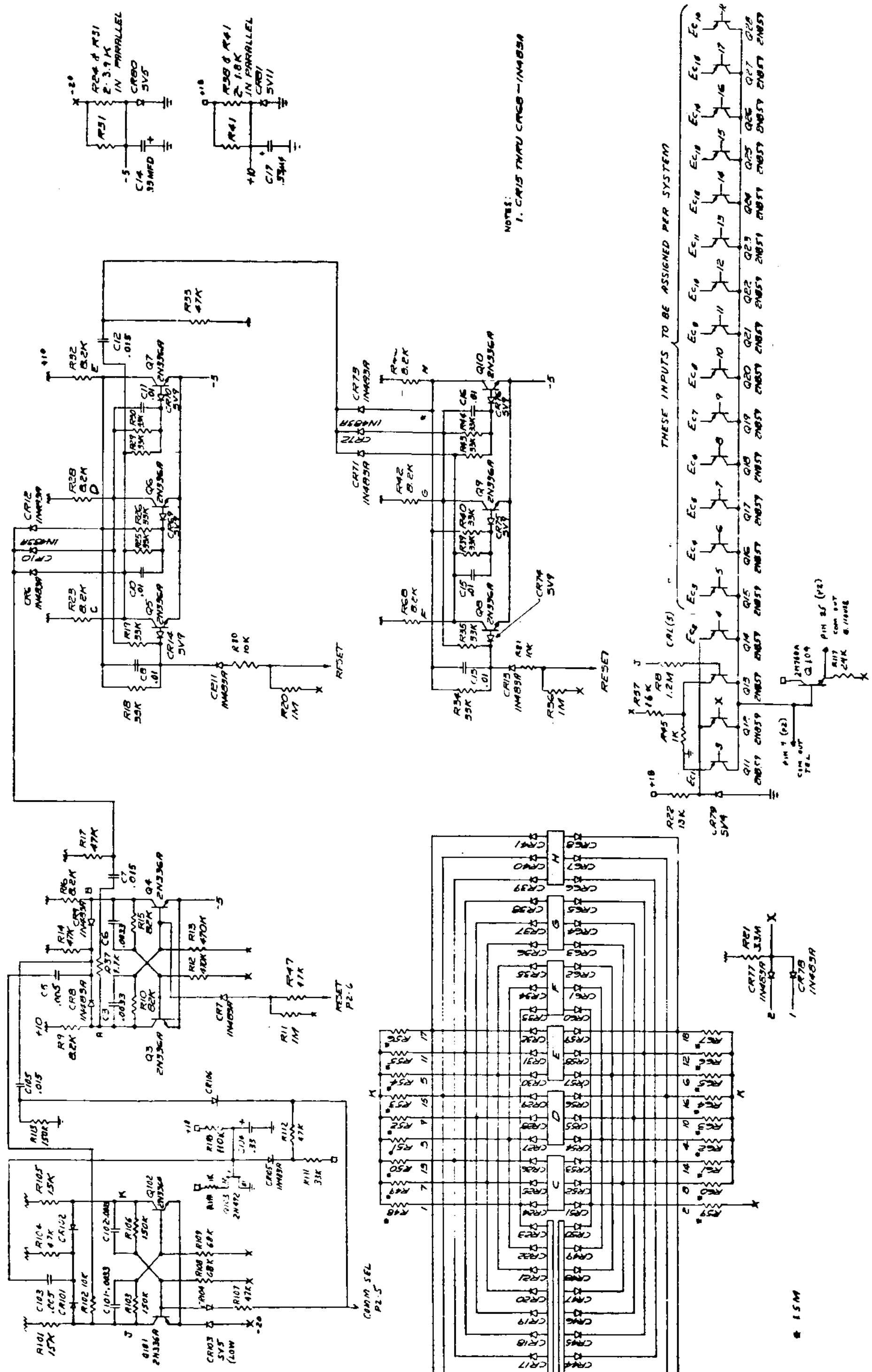

Figure 1.13 Schematic - Commutator - Monochromator

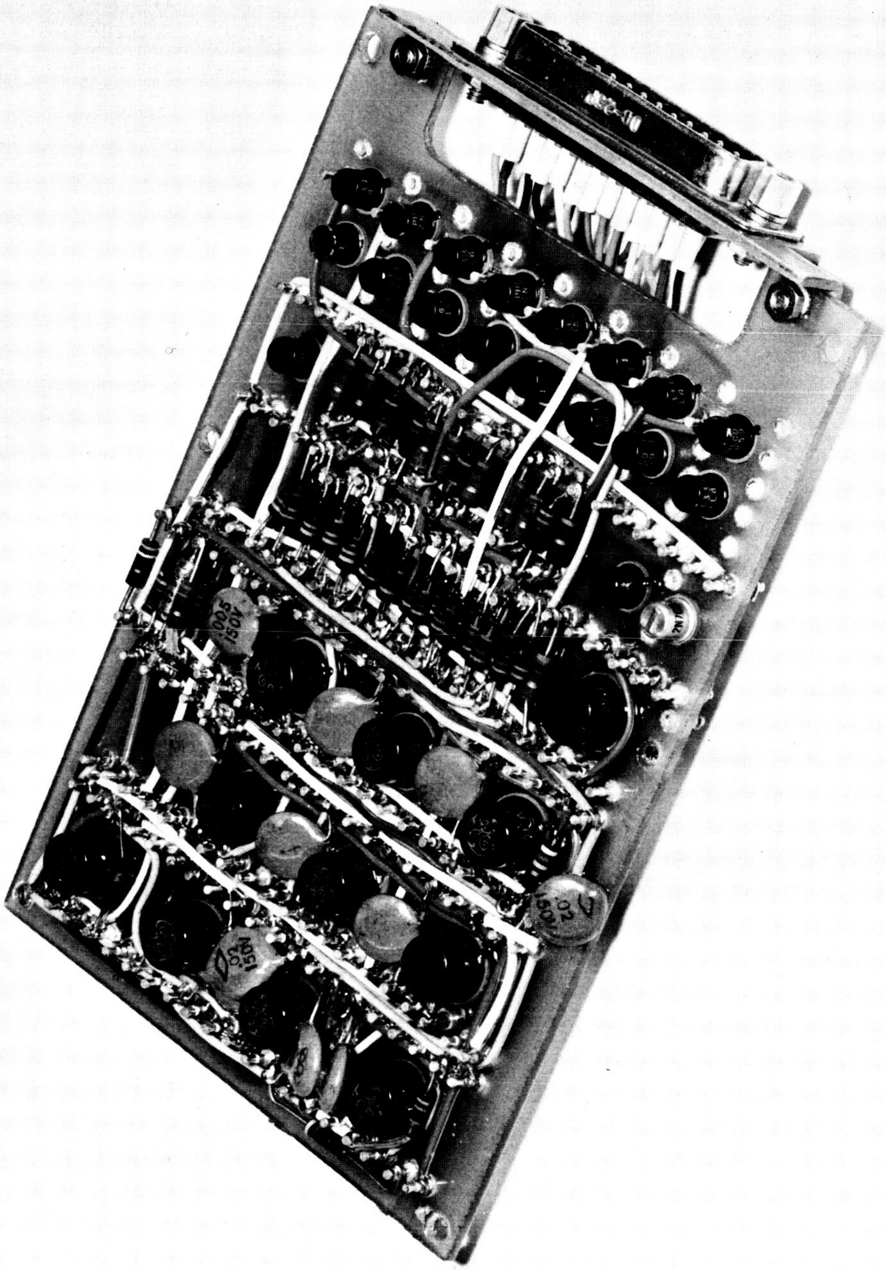

Figure 1.14 Commutator - Monochromator

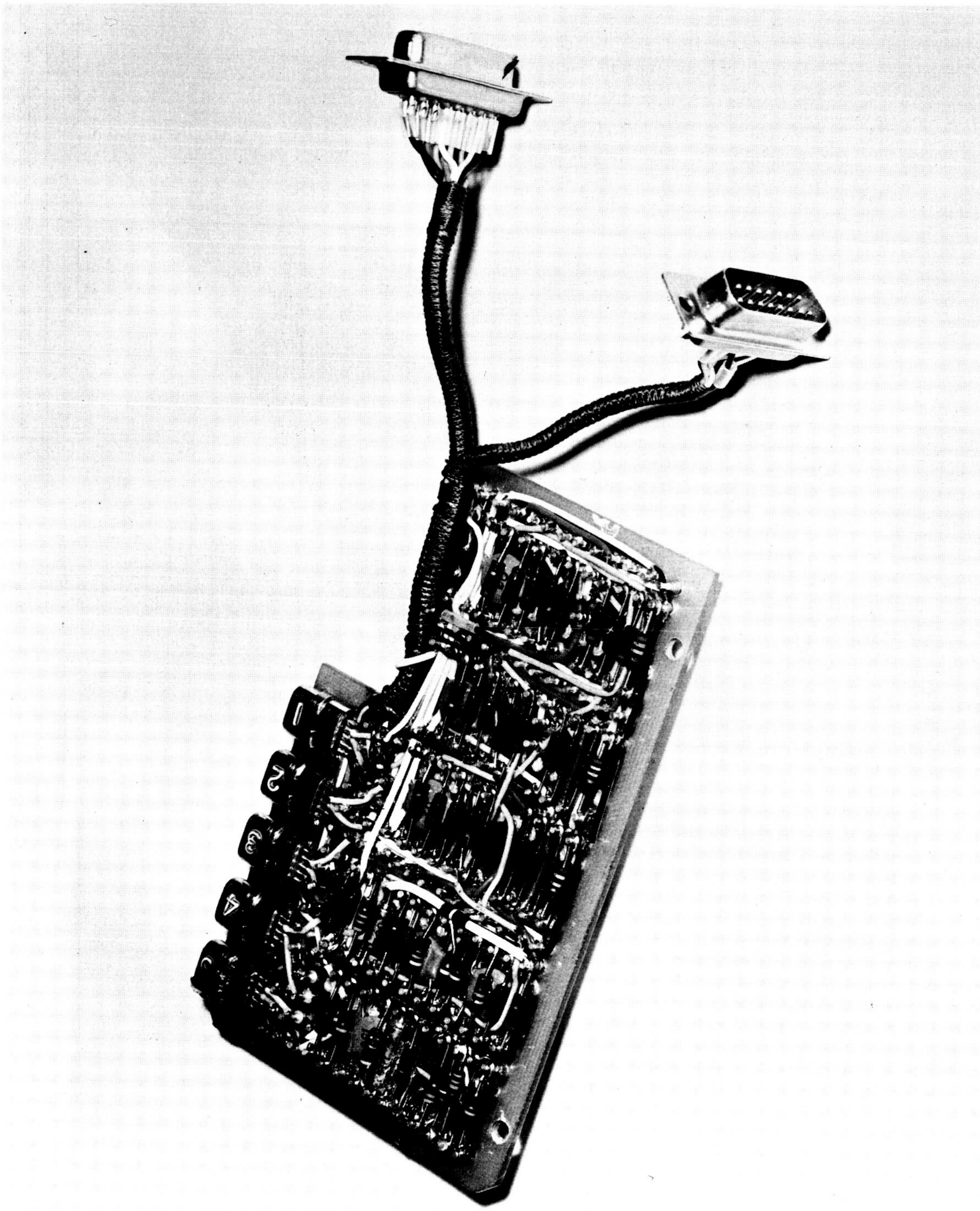

Figure 1.15 Fixed Slit Shutter Drive–Monochromator

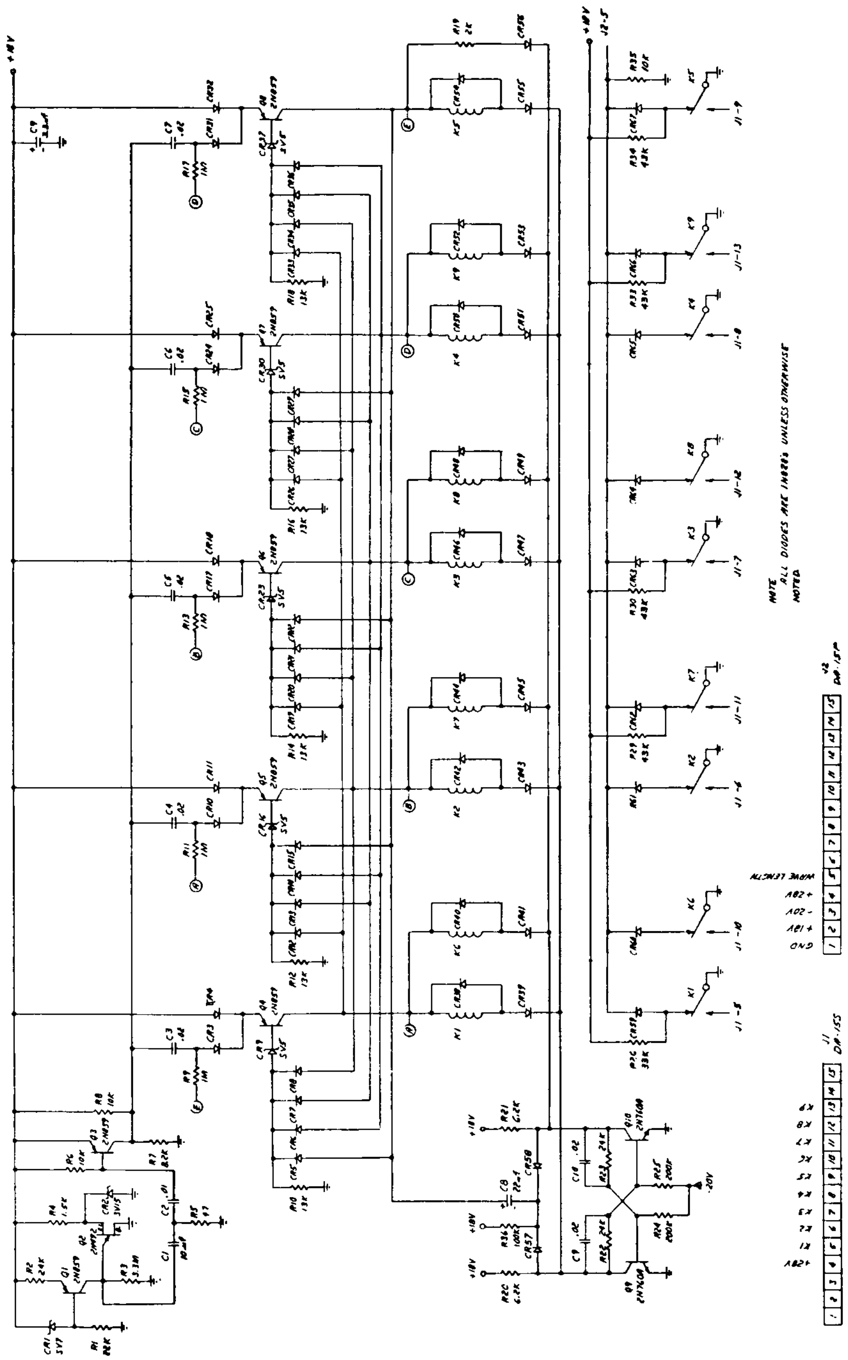

Figure 1.16 Schematic - Fixed Slit Shutter Drive-Monochromator

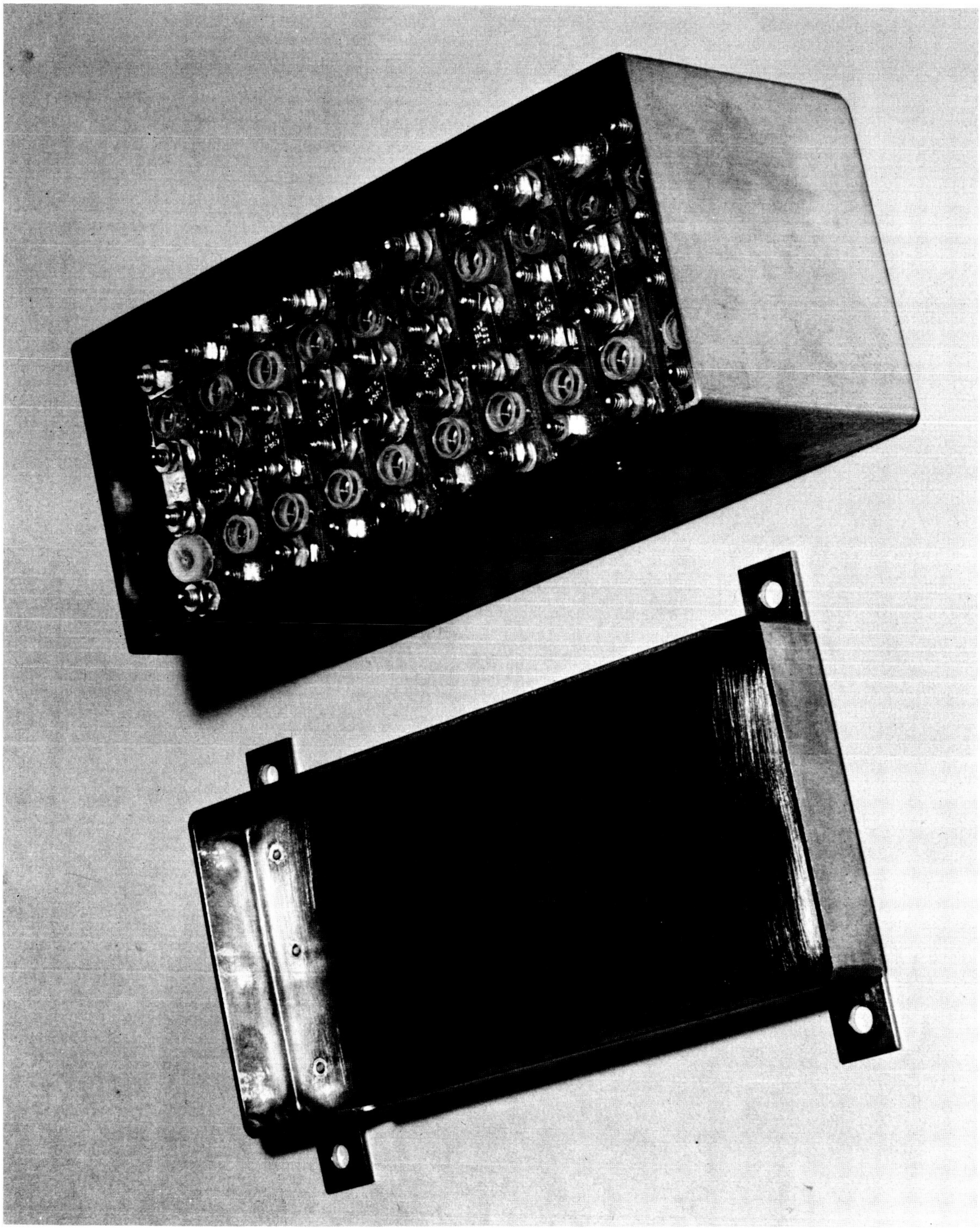

Figure 1.17 Battery-Monochromator

Figure 1.18 Monochromator Console

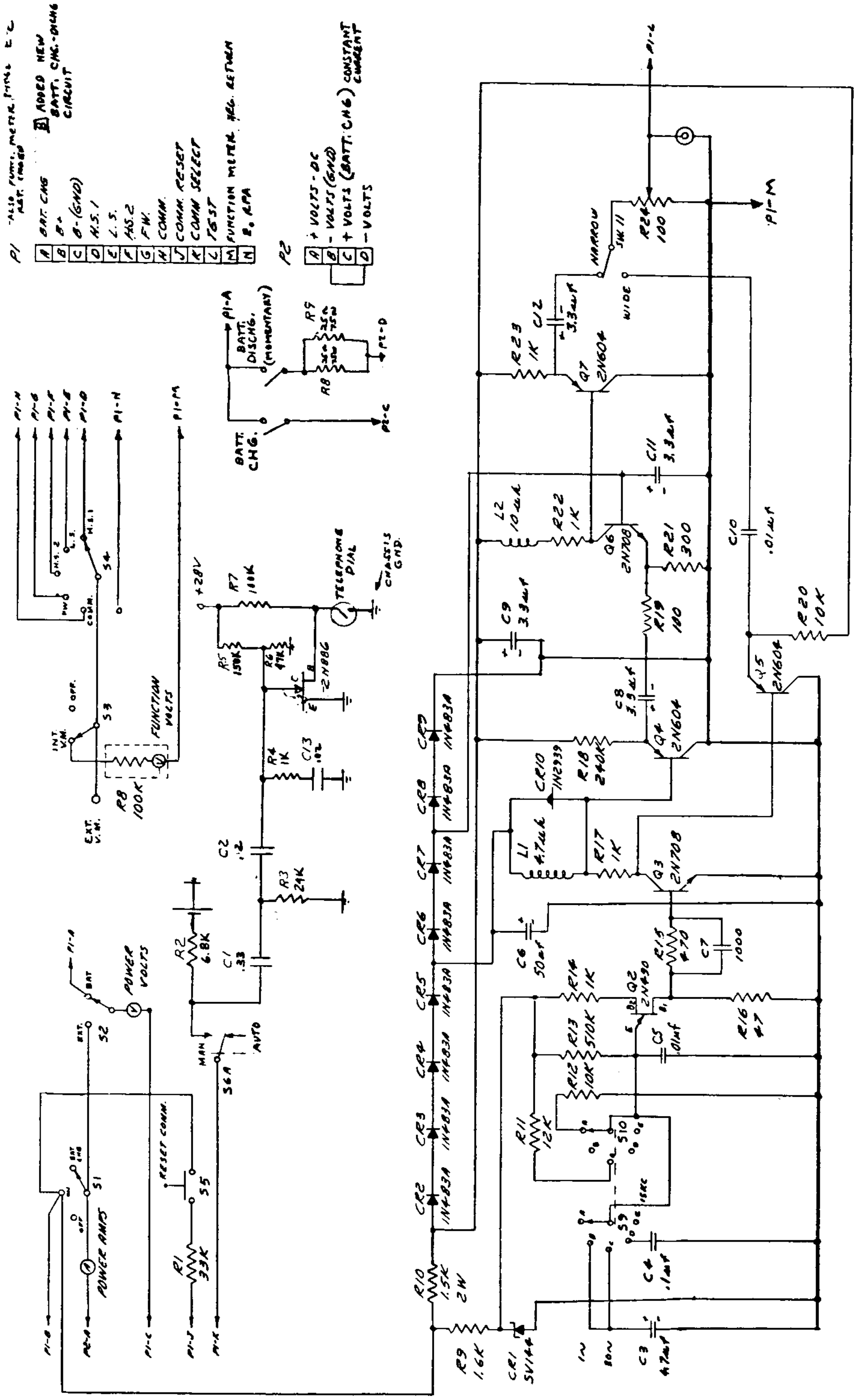

Figure 1.19 Schematic - Monochromator Console

Figure 1.20 Data Reducer Console

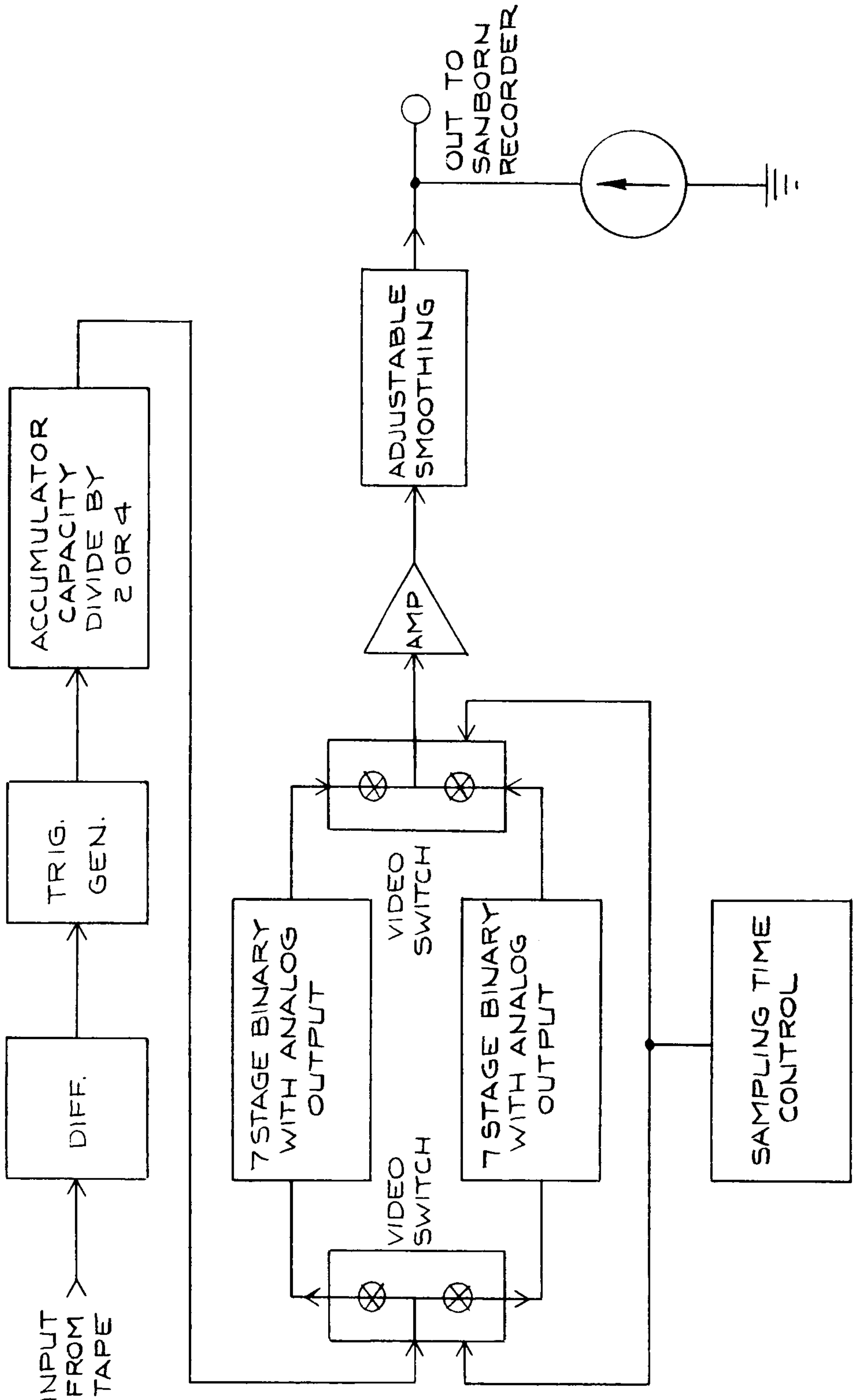

Figure 1.21 Data Reducer Block Diagram

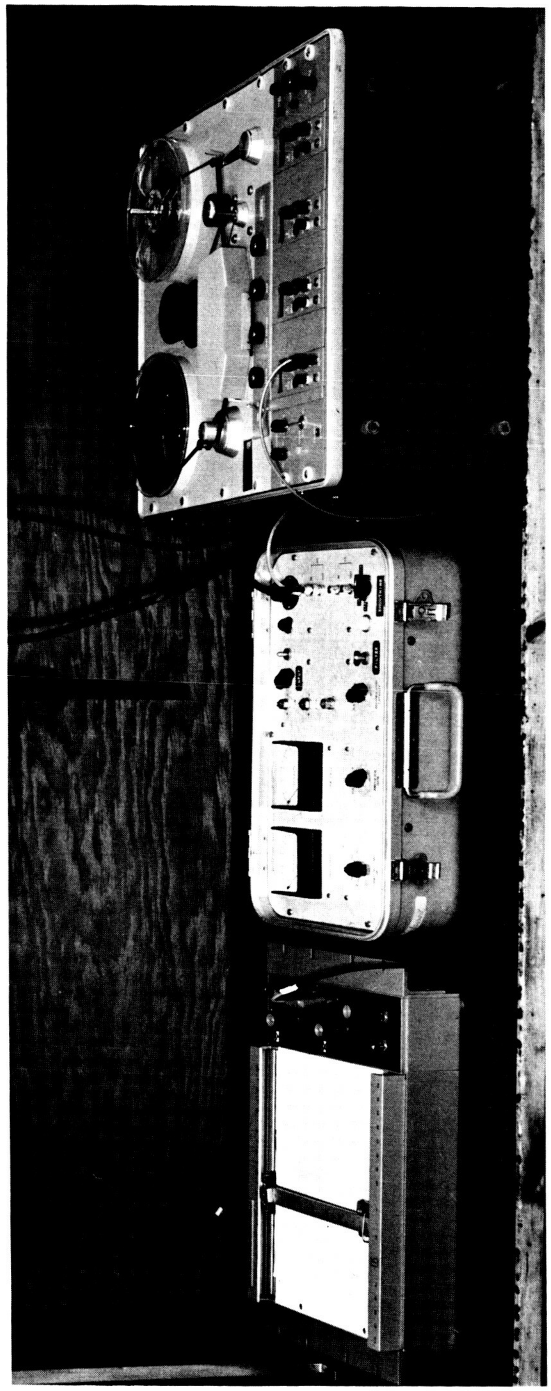

Figure 1.22 Data Reduction Set Up

2. EXTREME ULTRAVIOLET SATELLITE TELEMETERING MONOCHROMATOR

CONTENTS

2. EXTREME ULTRAVIOLET TELEMETERING MONOCHROMATOR FOR OSO SATELLITES

2.1 Introduction

The rocket monochromators described in Section 1 have measured the absorption of solar extreme ultraviolet radiation in the atmosphere. To complete the knowledge it is necessary to have a figure for the intensity of the solar flux incident on the earth's atmosphere. So far, few direct measurements have been made. However, with the advent of the artificial earth satellite, it is now possible to operate a monochromator for several months at an altitude above most of the earth's atmosphere and obtain data on the incident solar fluxes. The Orbiting Solar Observatory (OSO) series of spacecraft can carry and solar orient instruments similar to the rocket monochromators. Adcole Corporation has developed and built electronics for such monochromators, specifically for OSO B (S-17) and OSO C (S-57) NASA satellites under the contract described in this report.

2.2 Description of S-17 (OSO-B) Monochromator

The S-17 Monochromator is optically similar to the rocket monochromators. It has the same photomultiplier detector and pulse amplifier. However, the scanning system and the output electronics are different. Instead of a moving exit slit scanning the spectrum, four fixed slits are positioned at the wavelengths of interest on the Rowland circle. The rays from these four slits are passed through openings in a rotary drum to let each ray reach the photomultiplier cathode in turn and also stop all rays before sampling the first wavelength again. Each wavelength is sampled for one minute and all rays are blocked off for one minute giving a five minute complete cycle. The drum is turned by a Sigma "Cyclonome" motor driven by an electronic circuit operating from spacecraft power. The count rate from the photomultiplier is telemetered by a Pulse Code Modulation (PCM) system which requires more electronic circuitry than the FM-FM system used on the rocket monochromators. This PCM system makes use of "on board" data reduction and thus makes much more efficient use of the telemetry bandwidths. The S-17 electronics counts the detector pulses for 120 milliseconds in a 16-stage binary counter, then shifts out this binary number during the next 40 milliseconds, repeating this process continually. Every minute the wavelength being observed changes as described above. A more complete explanation of the electronics necessary for the PCM system is given in the description of the S-57 Monochromator in the next section of this report.

The S-17 Monochromator was developed to be used as a "back-up" instrument for either of two pointed instruments on the OSO-B satellite. As it turned out, both prime instruments were launched on the satellite and the S-17 Monochromators have not been used.

Three sets of electronics were produced: a prototype, flight and flight spare unit.

The operation of the electronics requires enabling signals from the spacecraft. For development and bench checkout Adcole built a test console to provide these signals.

2.3 Description of S-57 (OSO-C) Monochromator

The S-57 Monochromator was developed to orbit on the OSO-C satellite as one of the two prime pointed experiments.

The optical system is again similar to that of the rocket monochromators. The electronic system is similar to that of the S-17 Monochromator except that the moving belt with exit slit is used again, the belt being moved by a stepping motor. A photograph of the completed monochromator is shown in Figure 2.1.

The purpose of the experiment is to monitor solar radiation in the wavelength range from 250 to 1300 Angstroms. The instrument used to accomplish this is a grazing-incidence grating monochromator, scanning the spectral range at a rate of one complete scan every 5.44 minutes. The entrance slit and grating are fixed and scanning is accomplished by an exit slit cut in a continuous belt moving on the Rowland circle. The movement of the belt is a stepping movement so that the belt is stationary during data accumulation, and steps to the next position during readout. The instrument accumulates data, then reads out and steps the belt to the next position four times per main frame.

The photoelectric detector of the monochromator feeds pulses to a pulse amplifier which triggers a 16 bit counter shift register which uses two adjacent 8 bit words for readout. Each readout resets the counter shift register. The main frame words used for the photon counter are 1, 2; 9, 10; 17, 18 and 25, 26. This arrangement gives a pulse accumulation time of 120 milliseconds and a count capacity of 65535. The counter shift register input is disabled once it is full so that it does not overflow if the input rate is too high but merely reads out the full count (all ones).

The pulses that activate the belt stepping motor are derived from the photon counter readout gates and are counted in another counter shift register called the wavelength counter. This counter shifter has 11 bits to record the 2040 belt positions but only the 8 least significant bits are read out. They are read out once per frame as word 22.

The wavelength counter is reset to zero at the beginning of each scan by means of an optical take-off on the belt drive pulley which uses light from the sun to energize a solar cell. However, there is also an inherent built-in reset since the wavelength counter is connected to reset itself on the 2040th pulse.

By command from the ground, the belt may be stopped at any one of the 2040 steps of the complete scan, so that variations in counting rate (intensity) for a particular wavelength of the solar spectrum may be recorded. The scan mode can be resumed by ground command. In addition, ground command can be used to make the belt step one-fourth as often or only once per main frame, thus giving four readings of the same data.

The experiment uses both day and orbit power. The orbit power is used in the belt drive and wavelength readout circuits so that the belt position readout is operative during satellite night. However, the belt is not stepped during the night.

The experiment may be commanded at any time.

A functional block diagram is given in Figure 2.2 and the complete diagram in Figure 2.3.

A logic and timing diagram is given in Figure 2.4 and a functional diagram of the command system is shown in Figure 2.5.

The majority of the electronics is contained in two boxes, one at the front top of the casting and the other at the bottom rear. The boxes plug into each end of the casting with their connectors mating with a wireway which ties all the electronics together and to the main instrument connectors. A photograph of the rear electronics box is shown in Figure 2.6.

This rear box contains four plug-in circuit boards with low voltage power supplies, the photon counter shift registers and logic, the pulse post amplifier and a solid state commutator. The pulse pre-amplifier is located in a separate box near the photomultiplier. The commutator is used to time share 4 voltage monitors and 2 temperature monitors on one analog output channel. Also in the rear box is a reference pulse generator which can be energized to produce a test signal that is fed into the electronics system to confirm its proper operation. This generator is, of course, de-energized during orbital operation.

The forward electronics box contains four circuit cards containing low voltage power supplies, the wavelength counter shift register and stepping motor drive electronics.

Schematic diagrams of the circuitry in both electronics boxes are given in Figures 2.7 through 2.15.

A high voltage power supply for the photomultiplier is also located in the casting.

Positive and negative voltages from rear electronics box are supplied to four outgassing grid assemblies and to a grid assembly in front of the input slit to prevent stray particles from entering the monochromator through the outgassing holes.

Three S-57 Monochromators were built: a prototype, flight and flight spare unit. All units have been calibrated and environmentally tested and all have been transported to Ball Brothers Research Corporation at one time or another for initial fitting, integration and sytem testing. The instrument performs well on the spacecraft in conjunction with the other experiments.

2.4 Environmental Testing

The monochromator was tested to the environmental specification required by the prime contractor. This testing includes vibration, acceleration, thermal shock and thermal vacuum operation. Harnesses were supplied by Adcole Corporation to permit these tests to be made at the environmental laboratory.

All three sets of electronics were thermally tested at Adcole Corporation before installation in the instrument and no trouble was encountered in the testing of the complete instrument.

2.5 Operation of the S-57 Monochromator

2.5.1 Calibration and Testing

As in the case of the S-17 instrument, the S-57 instrument requires enabling signals from the spacecraft for its operation. For development work and bench checkout and calibration, it was necessary to provide these signals in the absence of the spacecraft. Therefore Adcole Corporation built two similar test consoles to provide these signals. Two units were constructed because calibration of the prototype at the AFCRL laboratory was carried on at the same time testing was being done at Adcole Corporation and Ball Brothers Research Corporation.

A photograph of one of the consoles is shown in Figure 2.16. The console controls and monitors input power to the instrument including a separate control of the high voltage. It generates clock and inhibit gates similar to the ones which normally are supplied by the spacecraft. It simulates the command system of the spacecraft so that the instrument's response to commands may be tested. One of the consoles also converts the serial binary wavelength position data from the instrument to a parallel octal BCD output that can be fed to a printer to give a permanent record of the operation of wavelength scanning function.

The console is used for all bench checks, for operation of the instrument during environmental testing and laboratory calibration.

A block diagram of the console is given in Figure 2.17 and timing diagram in Figure 2.18.

Readout of the count rate from the photomultiplier for calibration was simplified by taking an output from the fourth binary stage of the counter in the data shift register and driving a laboratory decade scaler. To get the correct reading the input gates to instrument from the console are turned off and the scaler reading is multiplied by 16.

To facilitate scanning the instrument to find the calibration wavelength, the stepping motor was controlled by an external drive box which reverses, single steps, and fast steps the motor.

The synchronization of the wavelenth position counters with the beginning of the optical scan is implemented by sunlight passing through a correctly positioned hole in the scanning belt. For bench checking this feature, a jig was constructed to hold a small incandescent lamp in position to simulate the sun. The orbit functioning of this system was checked at Adcole Corporation using a solar simulator to adjust the sensitivity of the circuit.

2.5.2 Orbital Operation and Data Format

The OSO-C spacecraft will be put into a circular orbit at a 300 mile altitude with the plane of the orbit about 30° from that of the equator. During each 95-minute orbit the instrument will be in the sun about 60 minutes. The solar pointing control will acquire the sun after about one minute of time and hold the instrument solar axis on the center of the sun within about one minute of arc.

The instrument is supplied with both orbit power and day power. Orbit power is "on" at all times after initial turn on and day power is "on" only during the part of the orbit during which the spacecraft is in the sunlight. All the data collecting electronics, including the multiplier high voltage power supply, use day power. The scanning drive and readout electronics use orbit power, since position information must be stored during satellite night. Scanning stops at night, then continues from the same wavelength at satellite dawn.

Initial turn on of instrument will be delayed until the 14th orbit to insure complete pump-out of the instrument.

The Data Processing Branch of NASA will process the playback data from the spacecraft and provide each experimenter with the data acquired by his experiment package plus necessary subcommutated data. This data will be on one-half inch wide magnetic tape written in binary tape characters (odd parity) with either 200 or 556 six-bit characters to the inch. Each eight-bit telemetered word shall be represented by 2 six-bit characters.

These tapes can be processed further at AFCRL to given analog plots of intensity versus wavelength.

At present, pre-launch data readout at Ball Brothers Research Corporation during testing is presented by a Control Data Corporation printer which prints each wavelength position number immediately followed by accumulated counts at that wavelength.

Launch of the OSO-C spacecraft is scheduled for 1965 from Cape Kennedy.

2.6 List of Figures

Figure

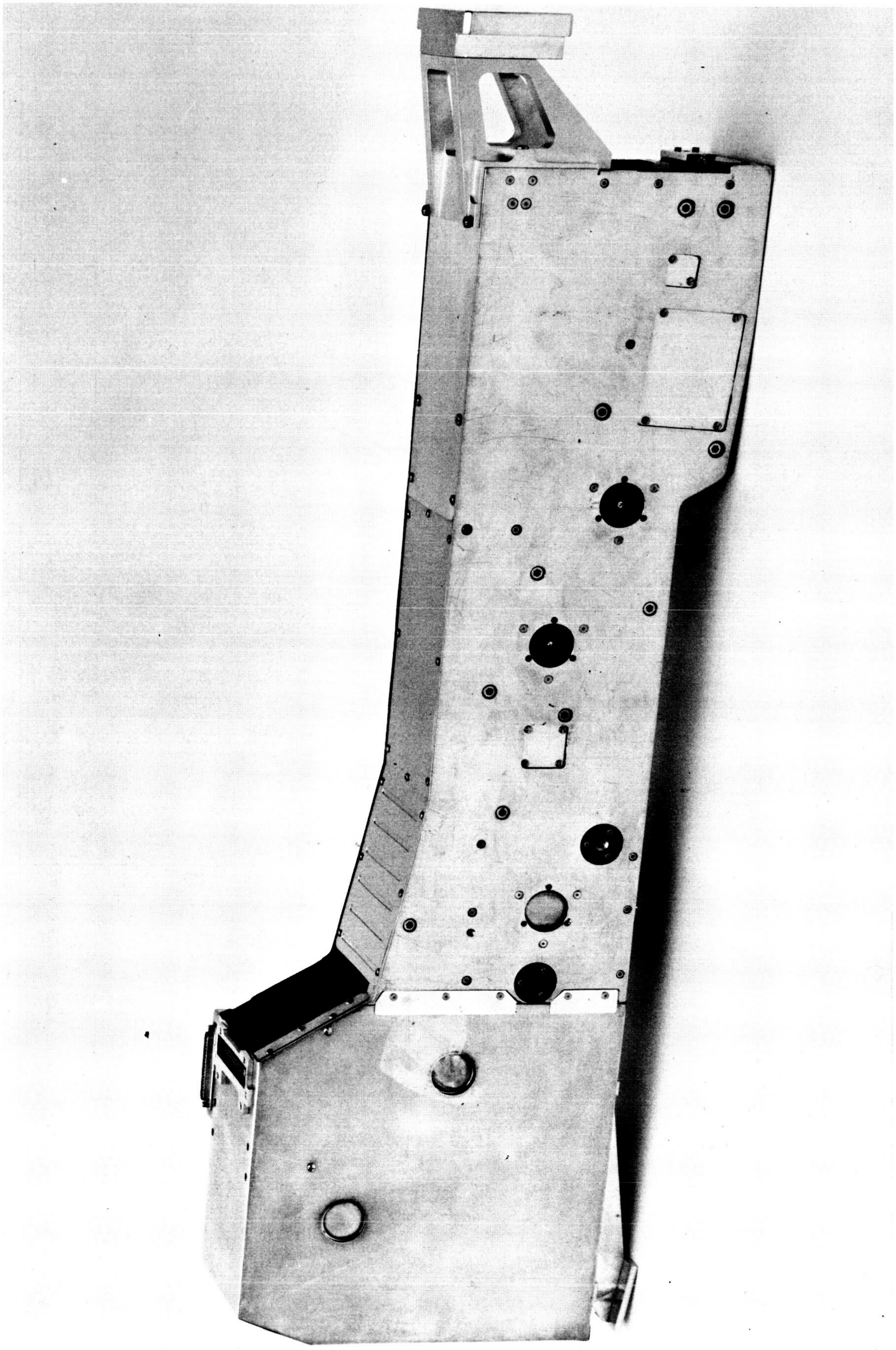

Figure 2.1 S-57 Monochromator

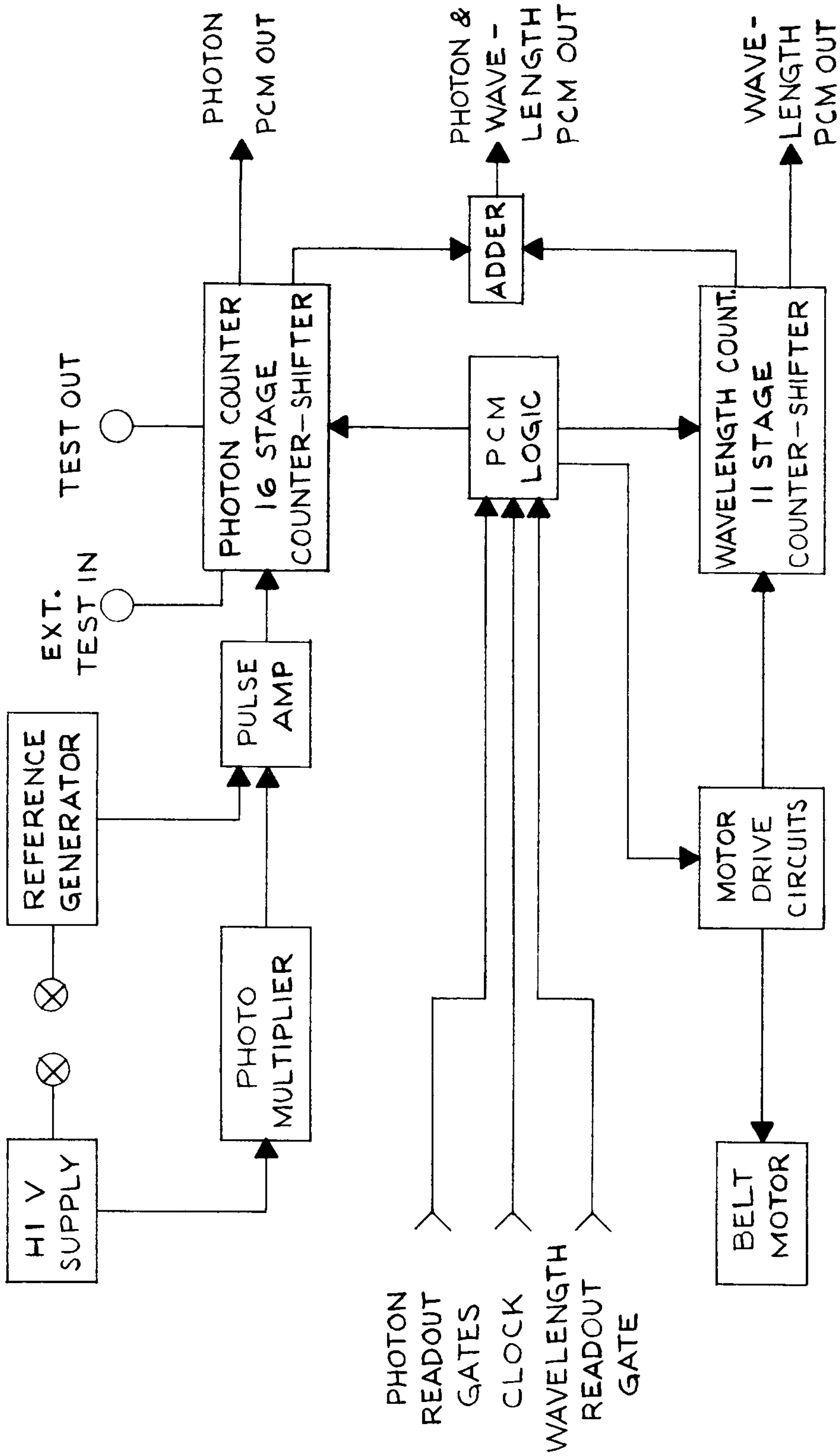

Figure 2.2 Functional Block Diagram - S-57 Monochromator

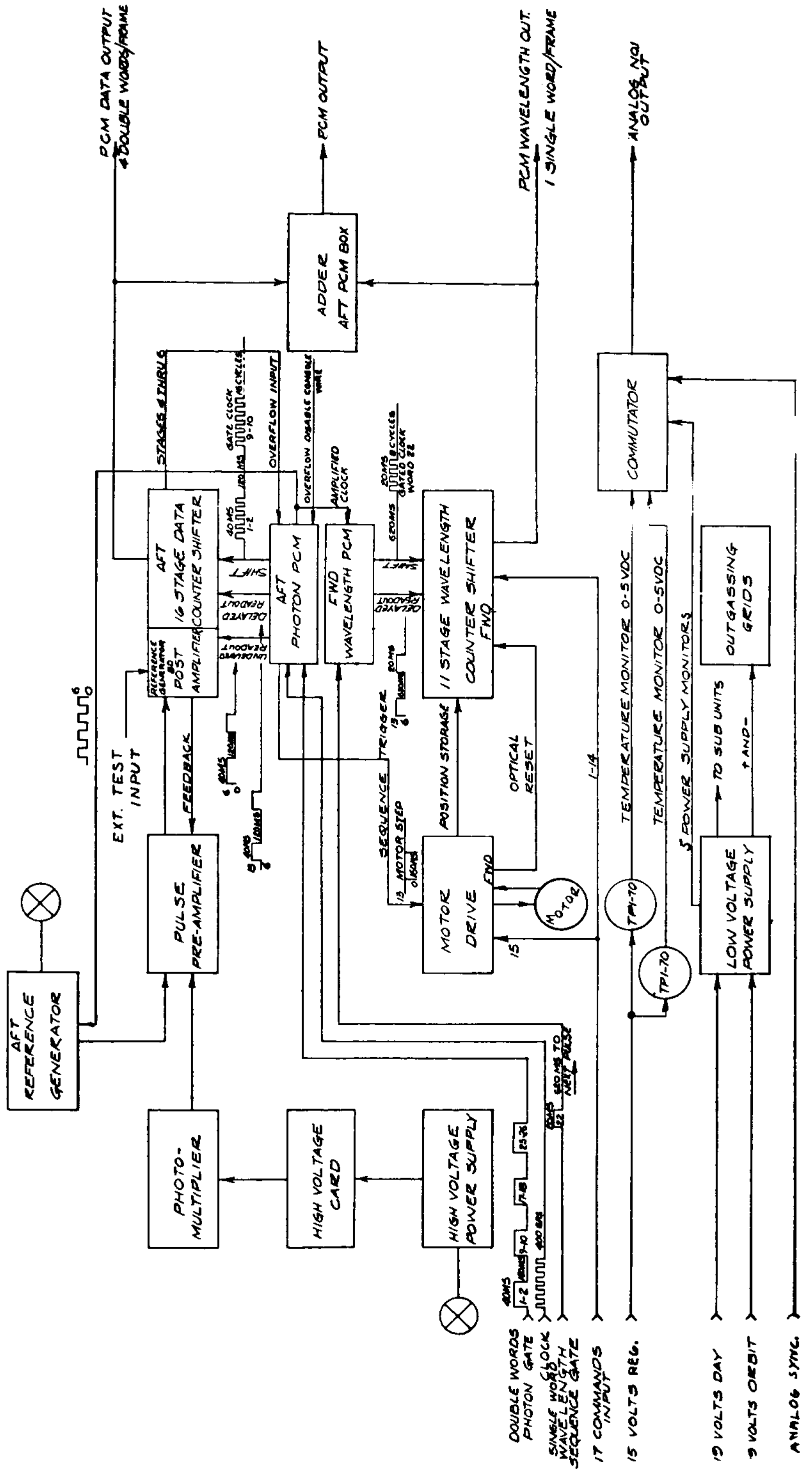

Figure 2.3 Block Diagram - OSO-C S-57

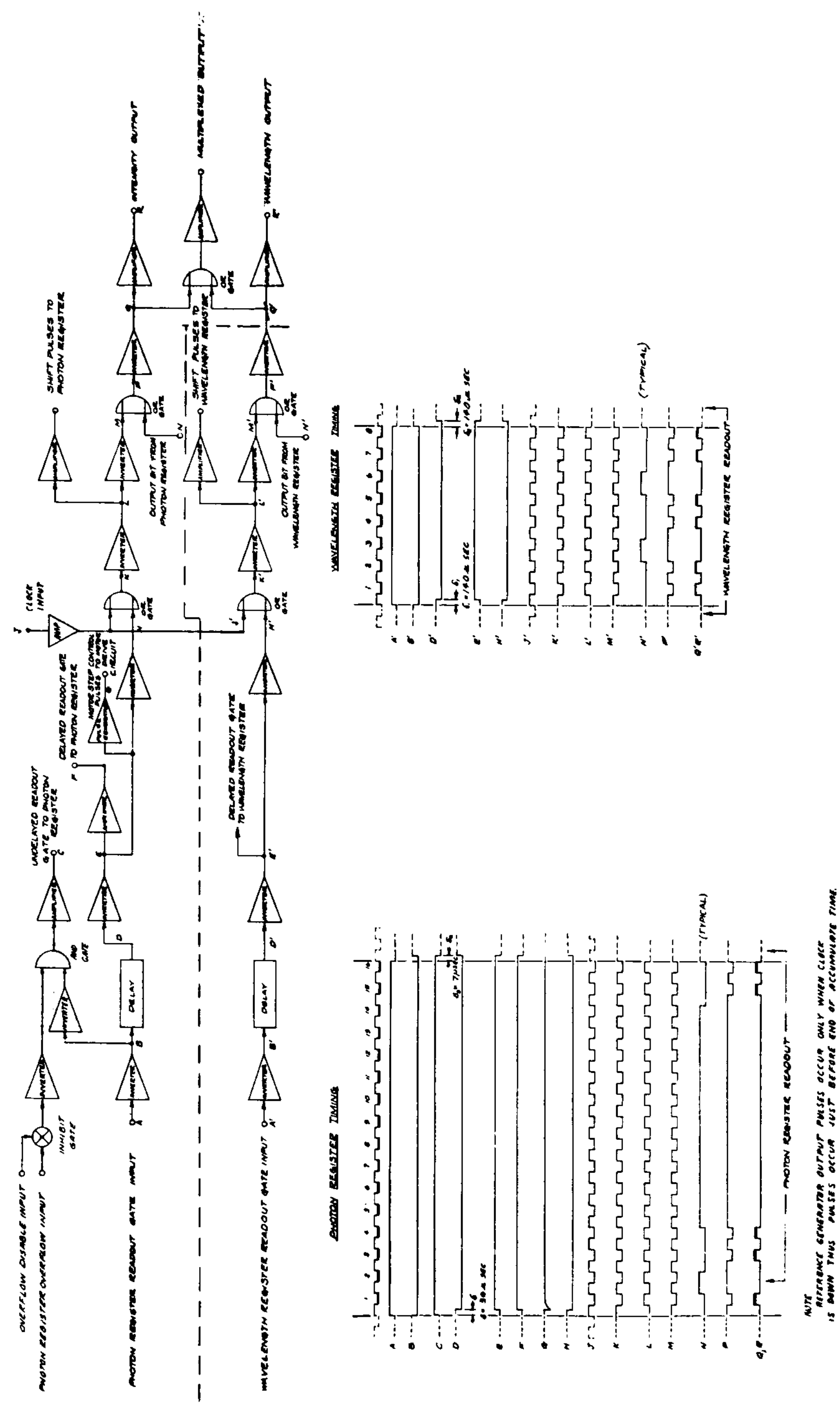

Figure 2.4 S-57 Satellite PCM Logic and Timing Diagram

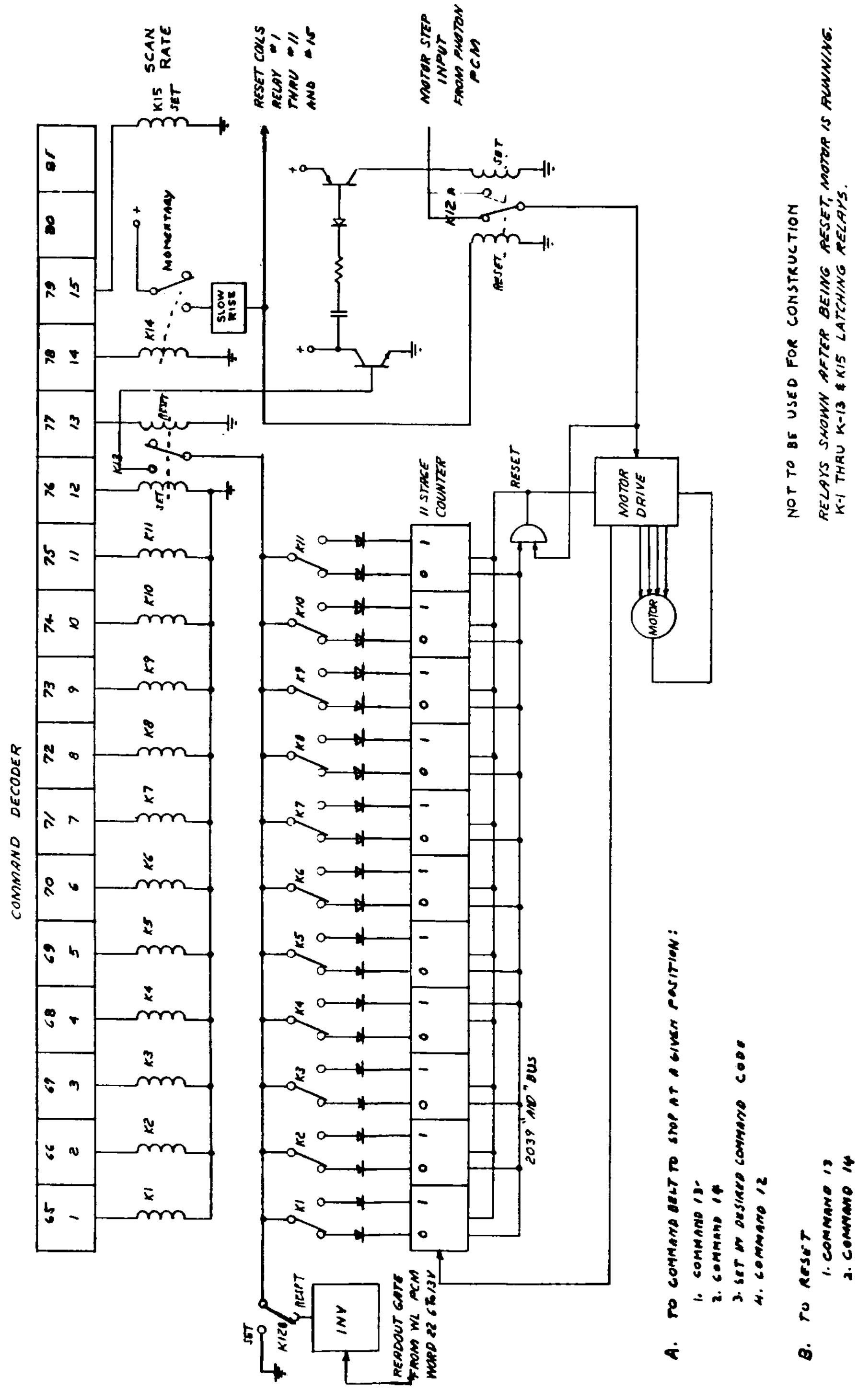

Figure 2.5 Command Circuitry S-57

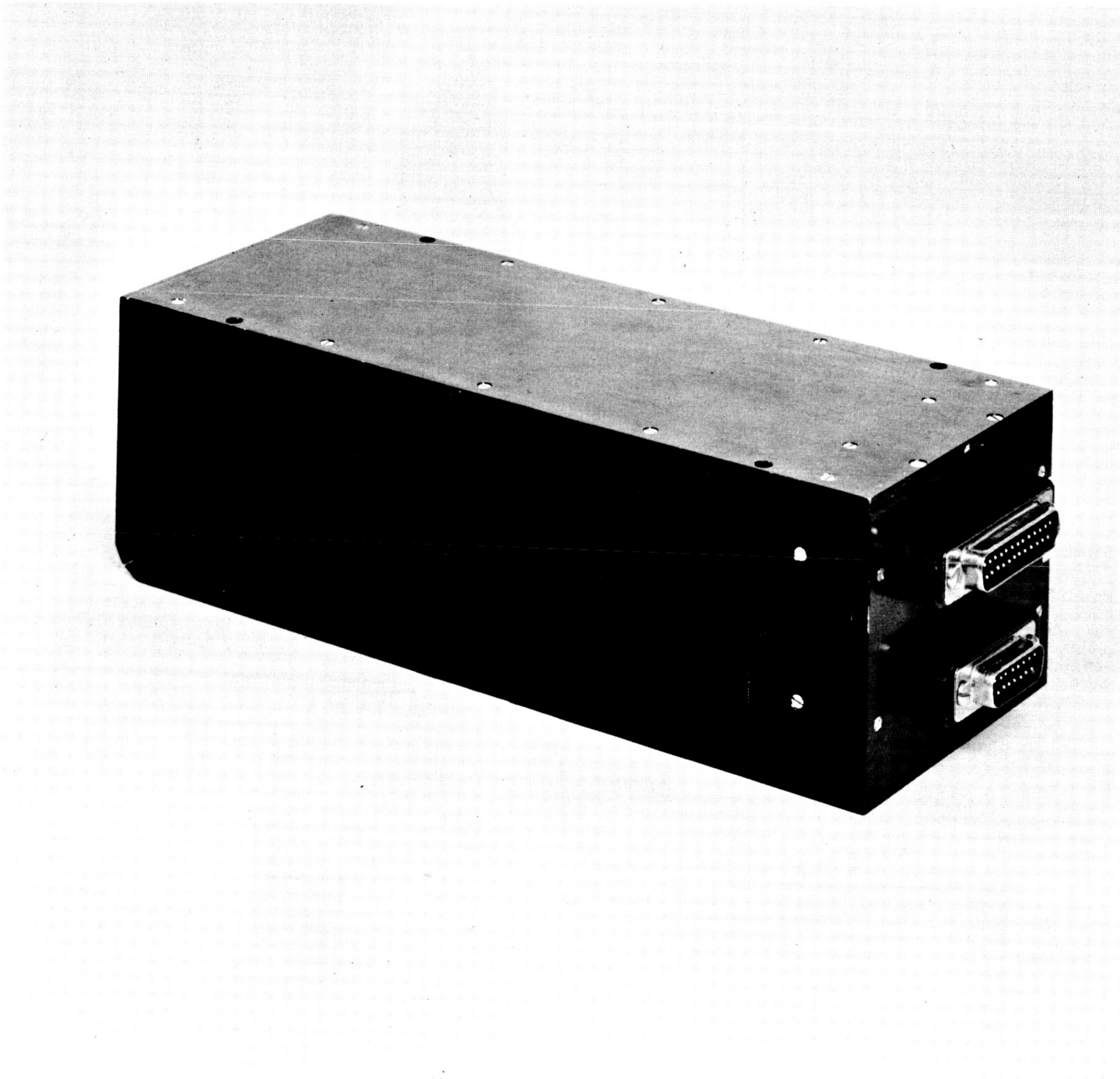

Figure 2. 6 S-57 Rear Electronics Box

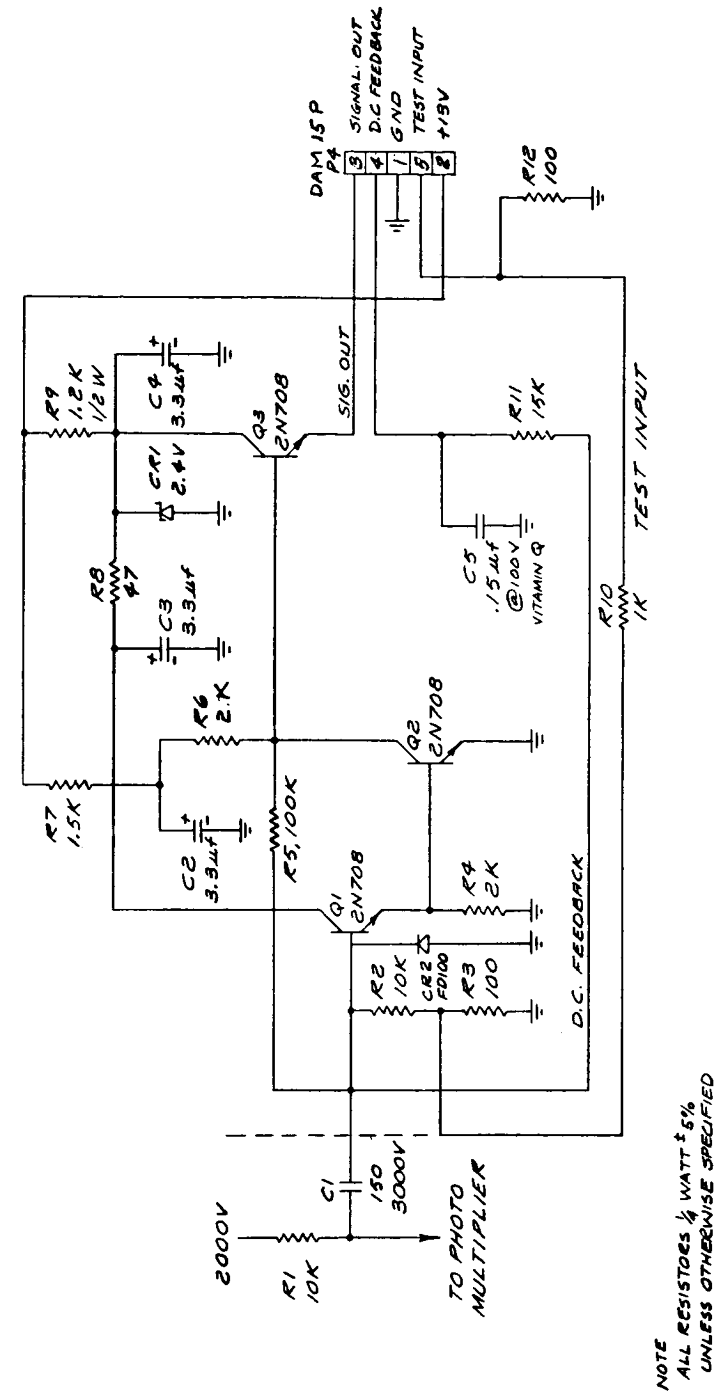

Figure 2.7 S-57 Monochromator Pulse Pre-Amplifier

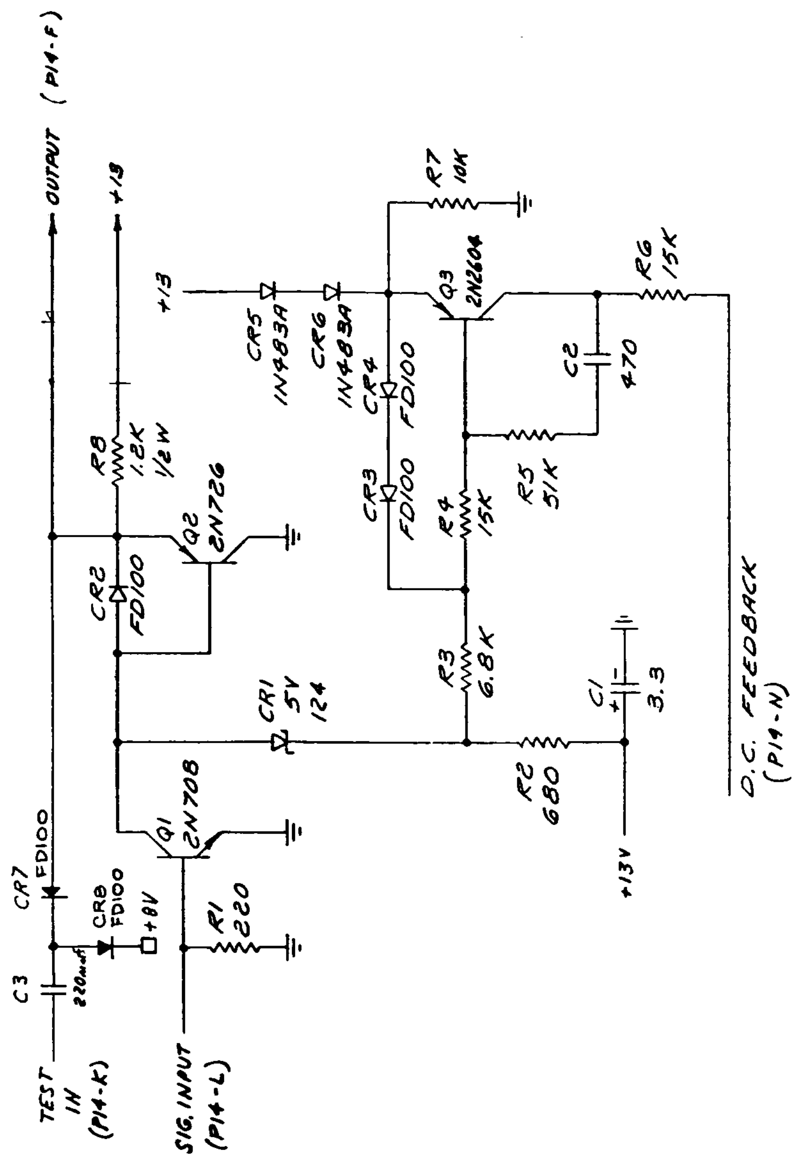

Figure 2.8 S-57 Monochromator Pulse Post-Amplifier

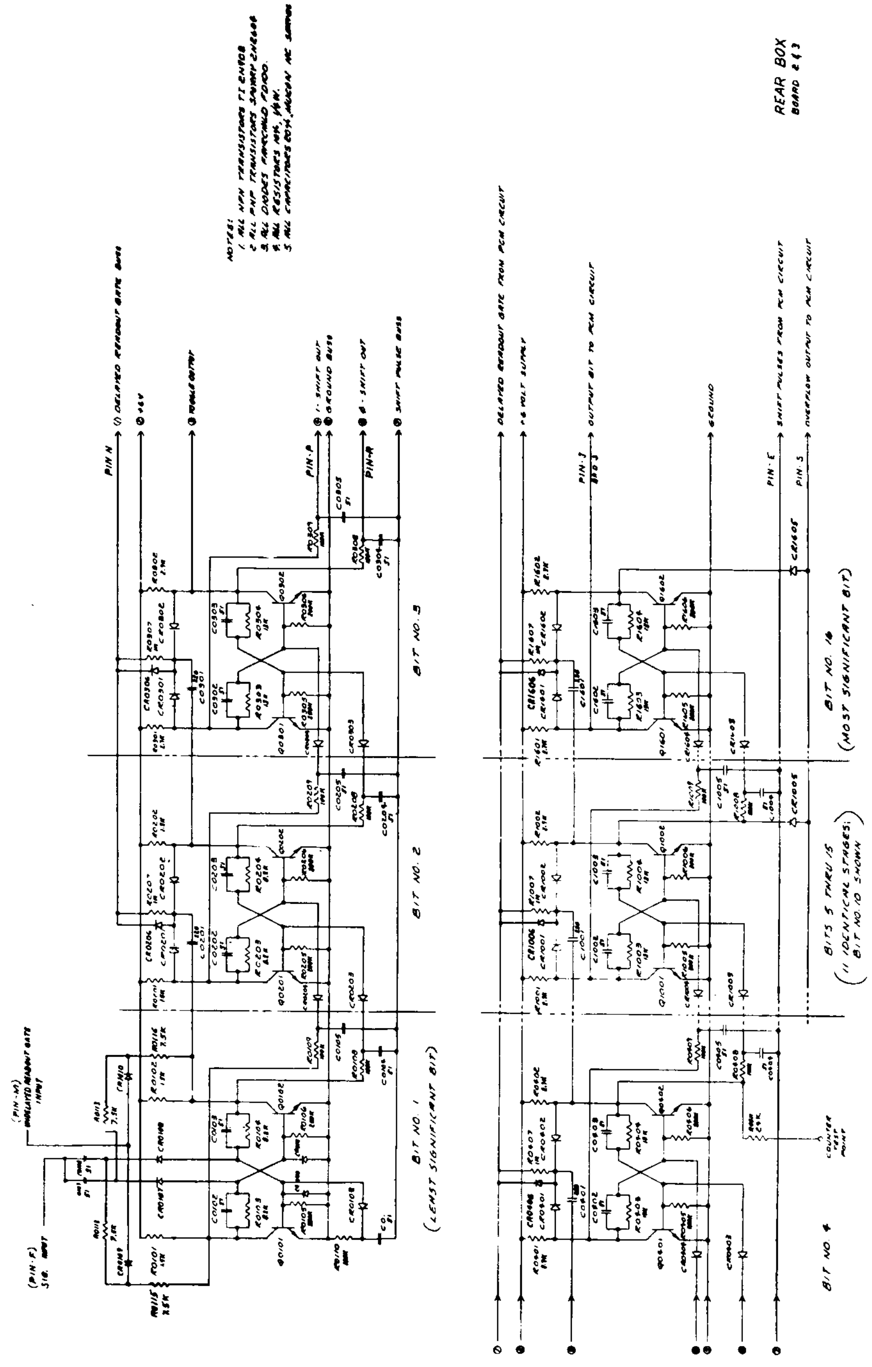

Figure 2.9 Schematic - S-57 Satellite 16 Bit Photon Register

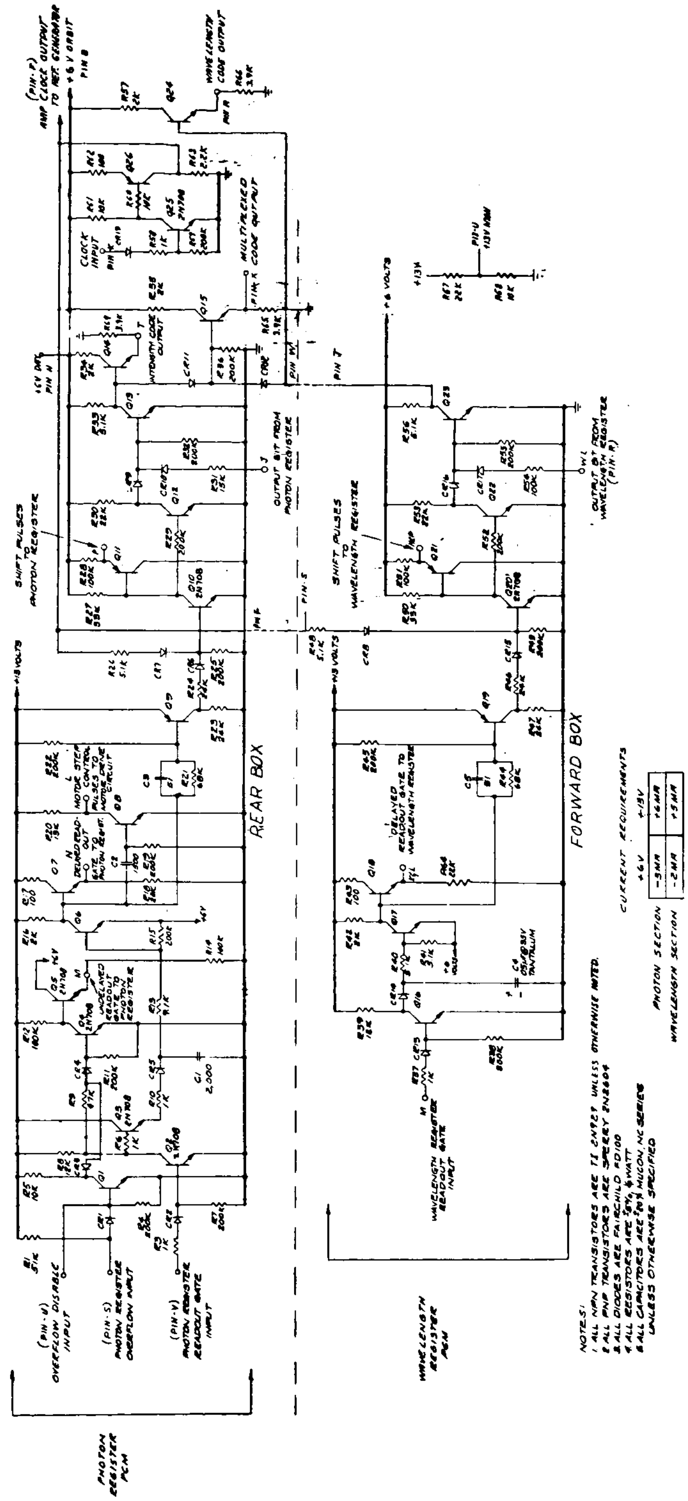

Figure 2.10 Schematic Diagram - S-57 Satellite PCM Circuit Board #4

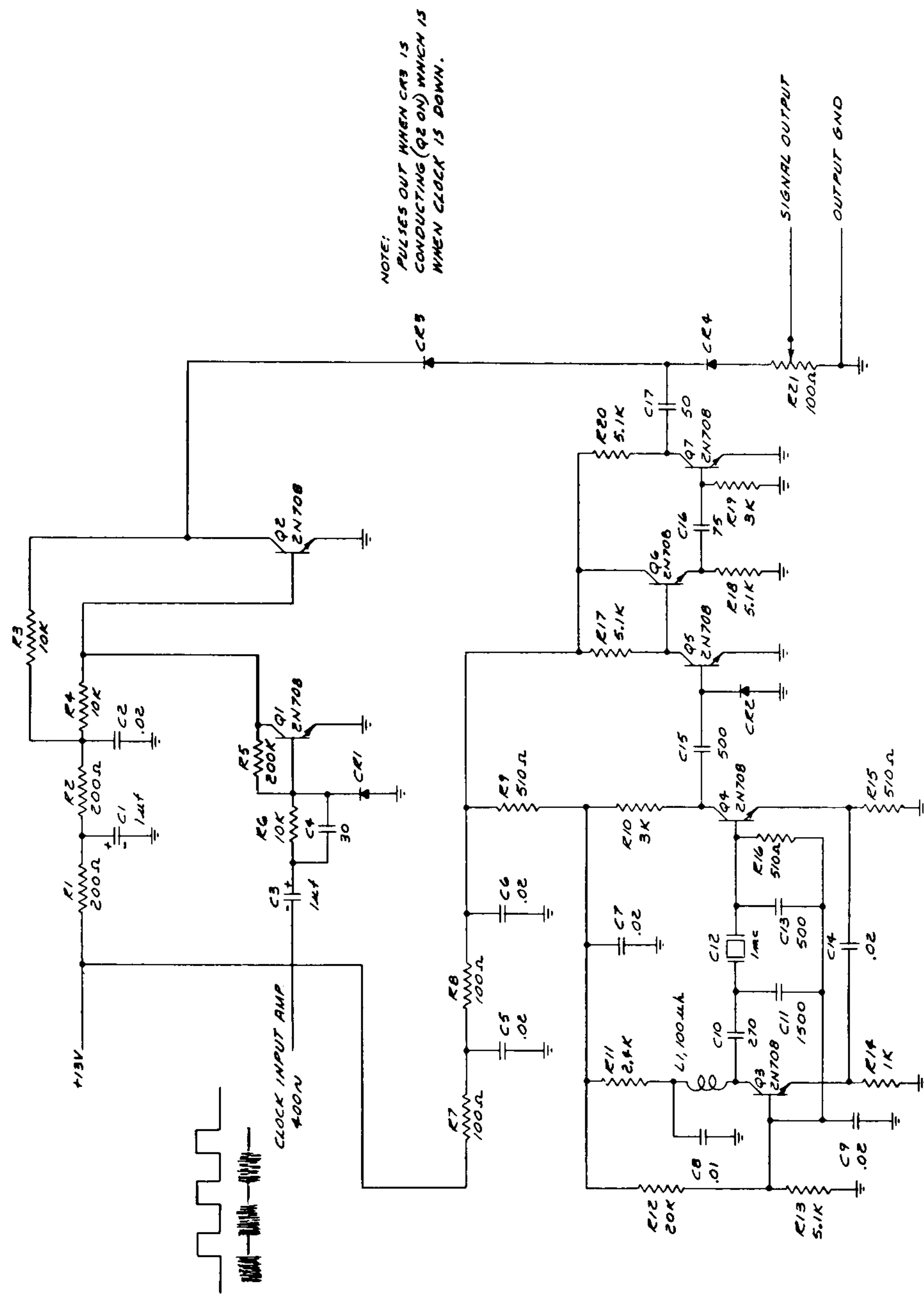

Figure 2.11 Schematic - Reference Generator S-57

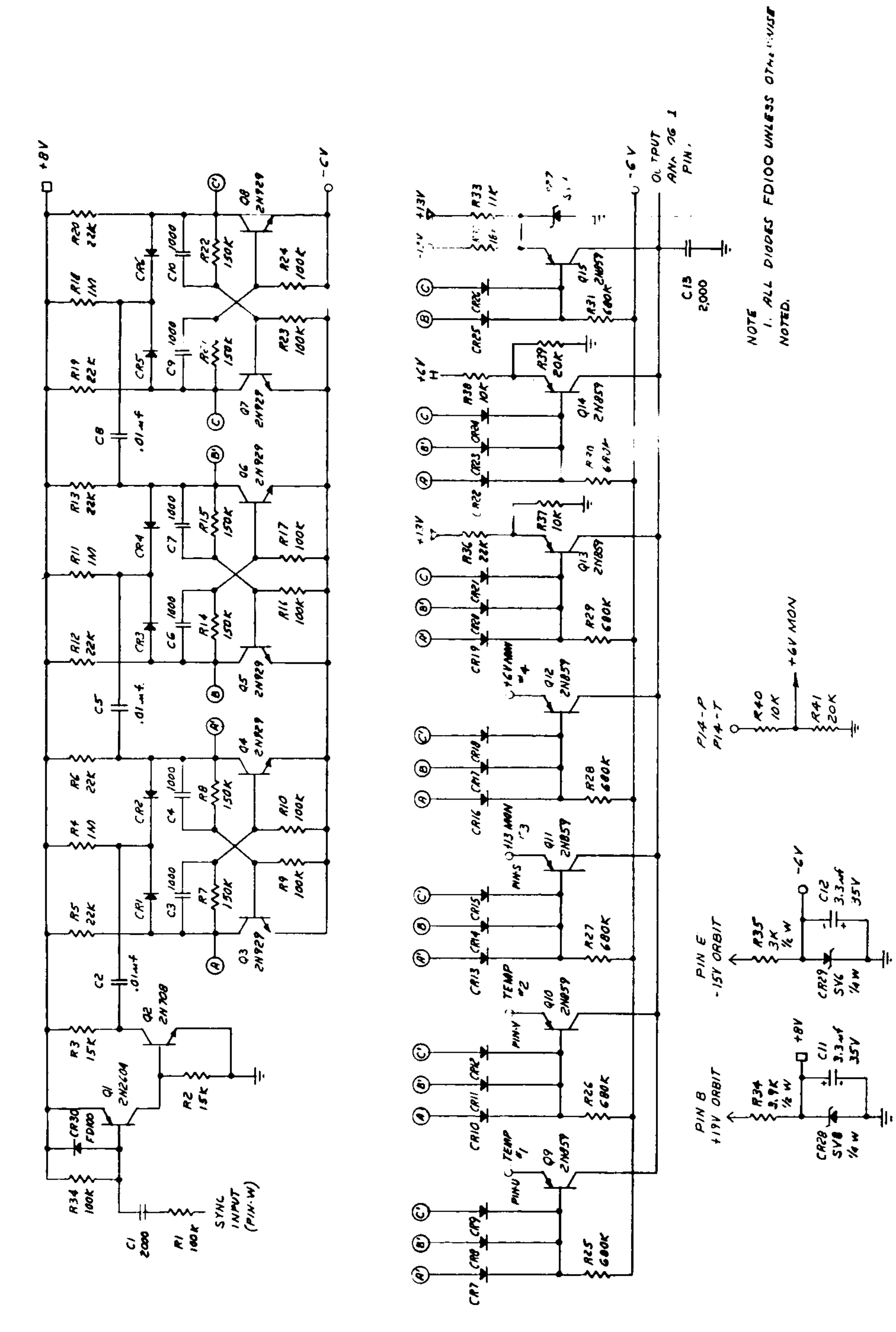

Figure 2.12 Schematic - Subcommutator Board #1 Rear Unit
S-57

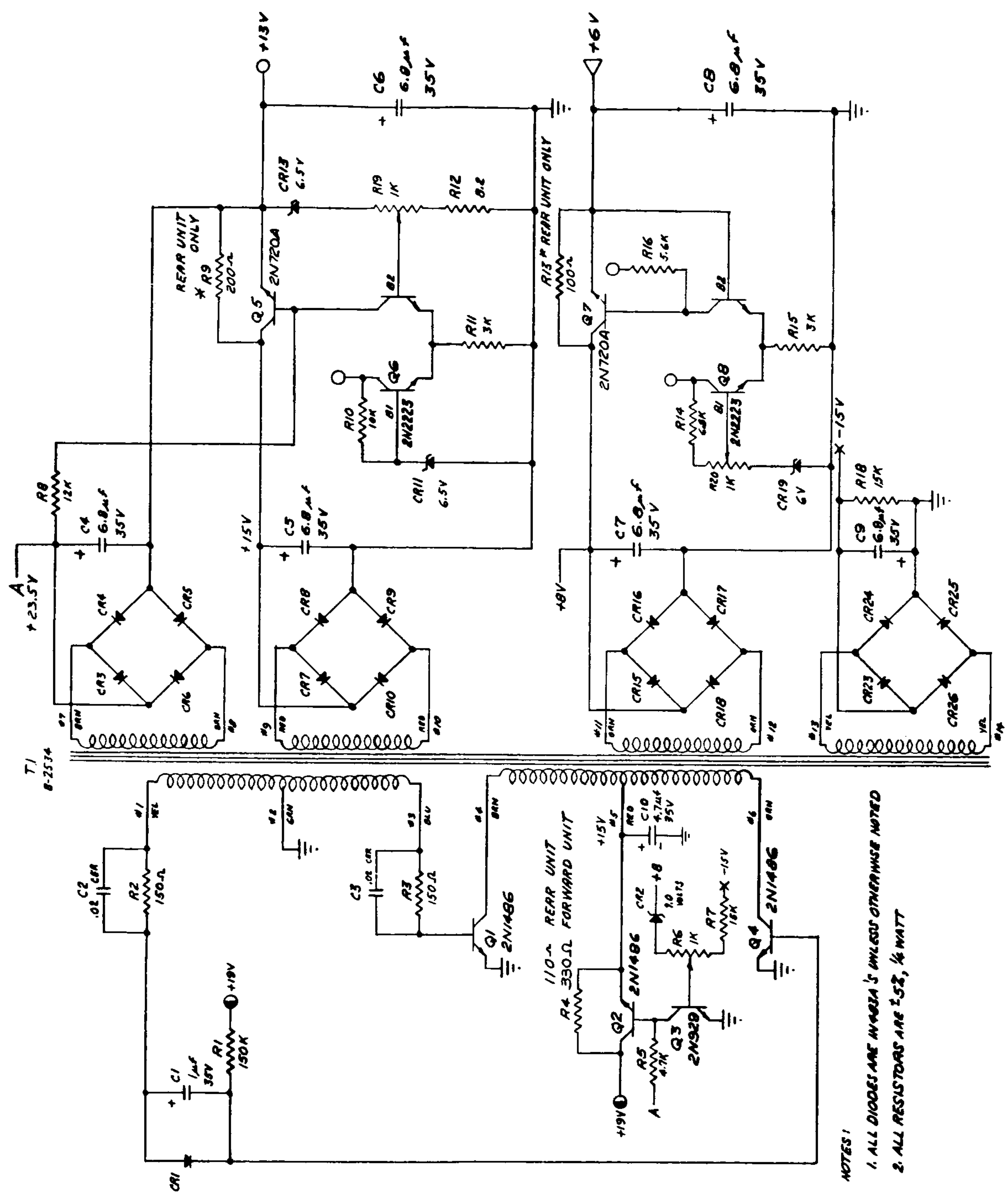

Figure 2.13 Schematic - Power Supply S-57

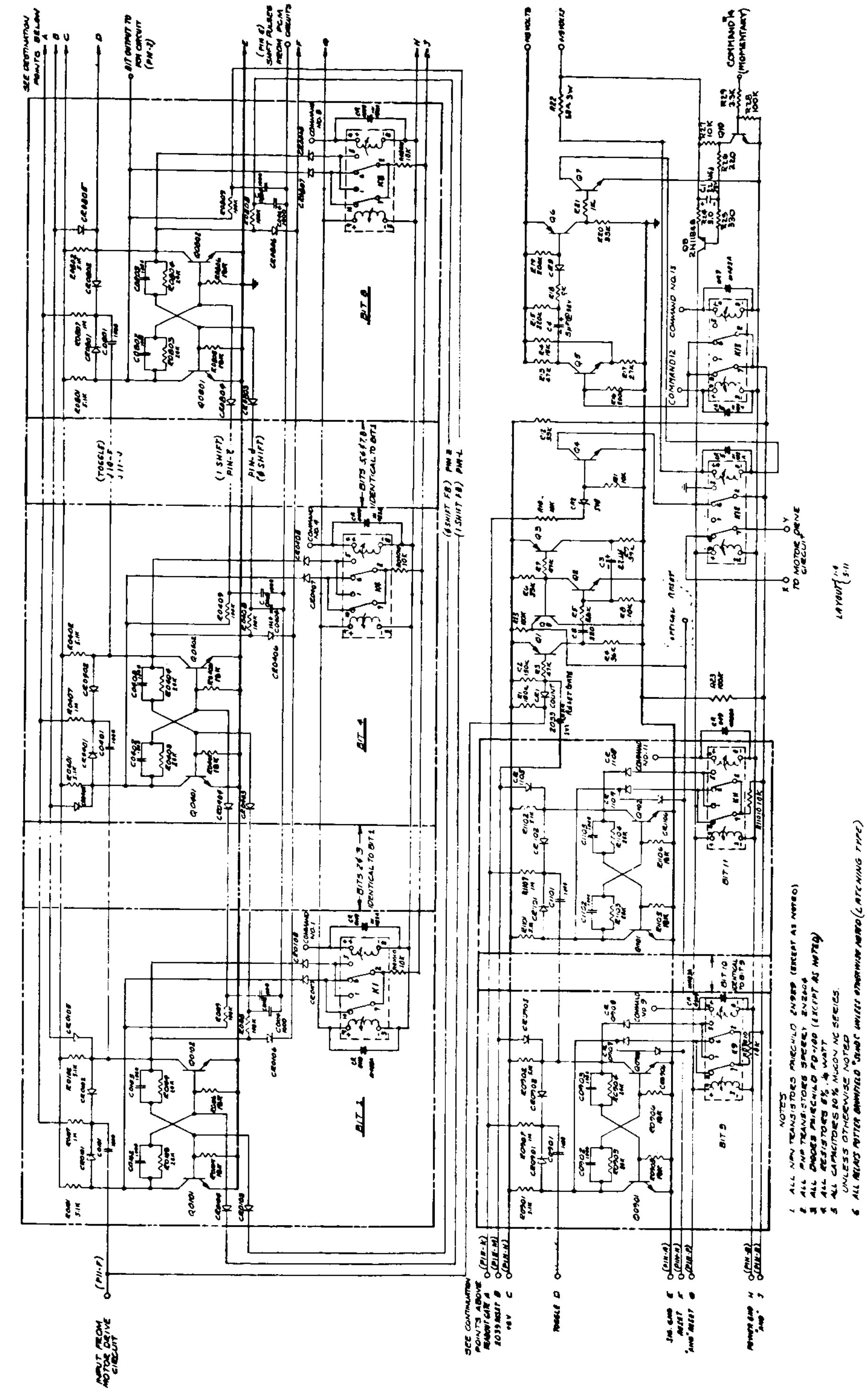

Figure 2.14 Schematic Diagram - Satellite Wavelength Register and Command Circuit

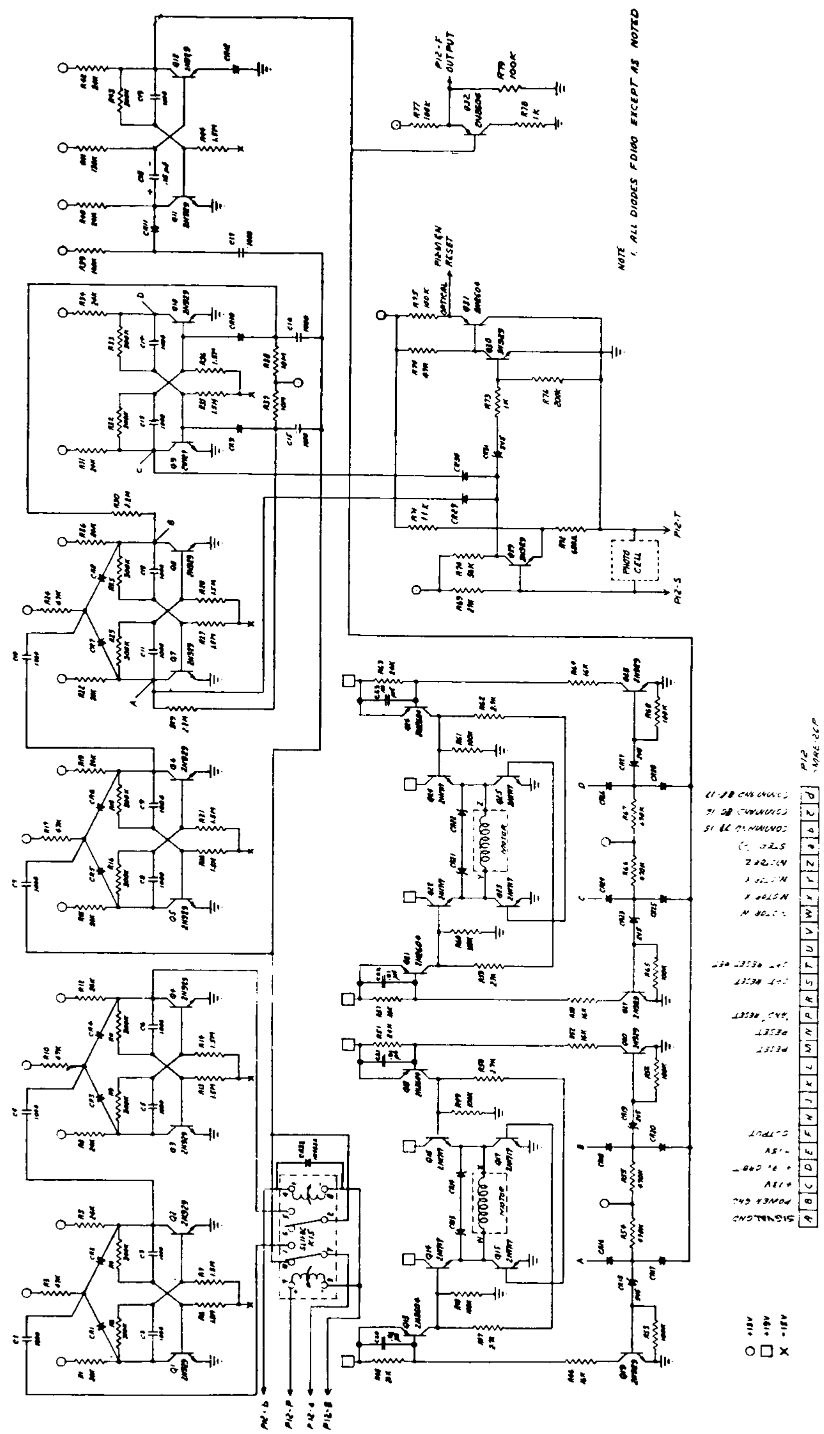

Figure 2.15 Schematic - Motor Drive S-57 Satellite

Figure 2.16 S-57 Test Console

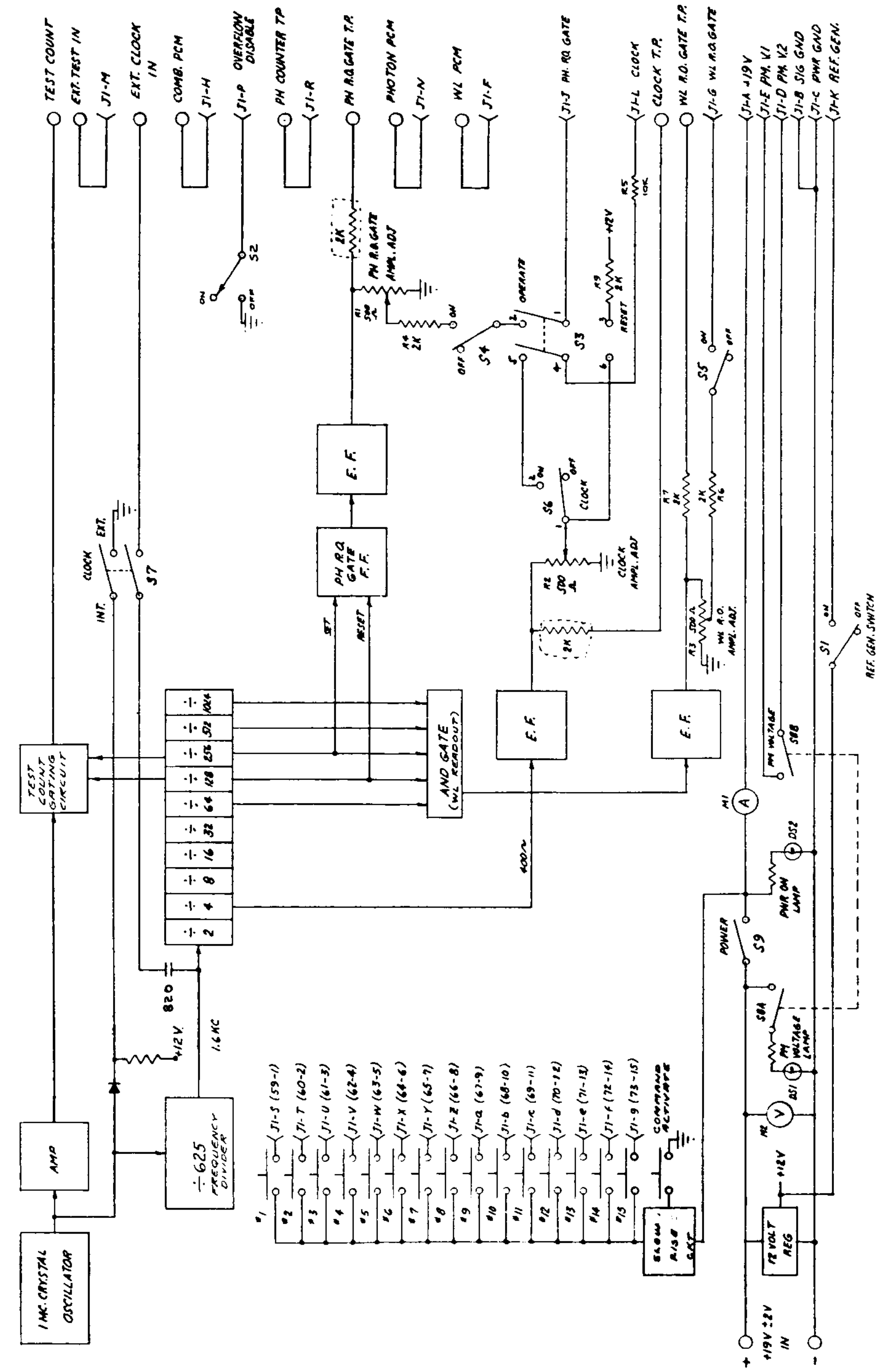

Figure 2.17 Block Diagram - Test Console S-57

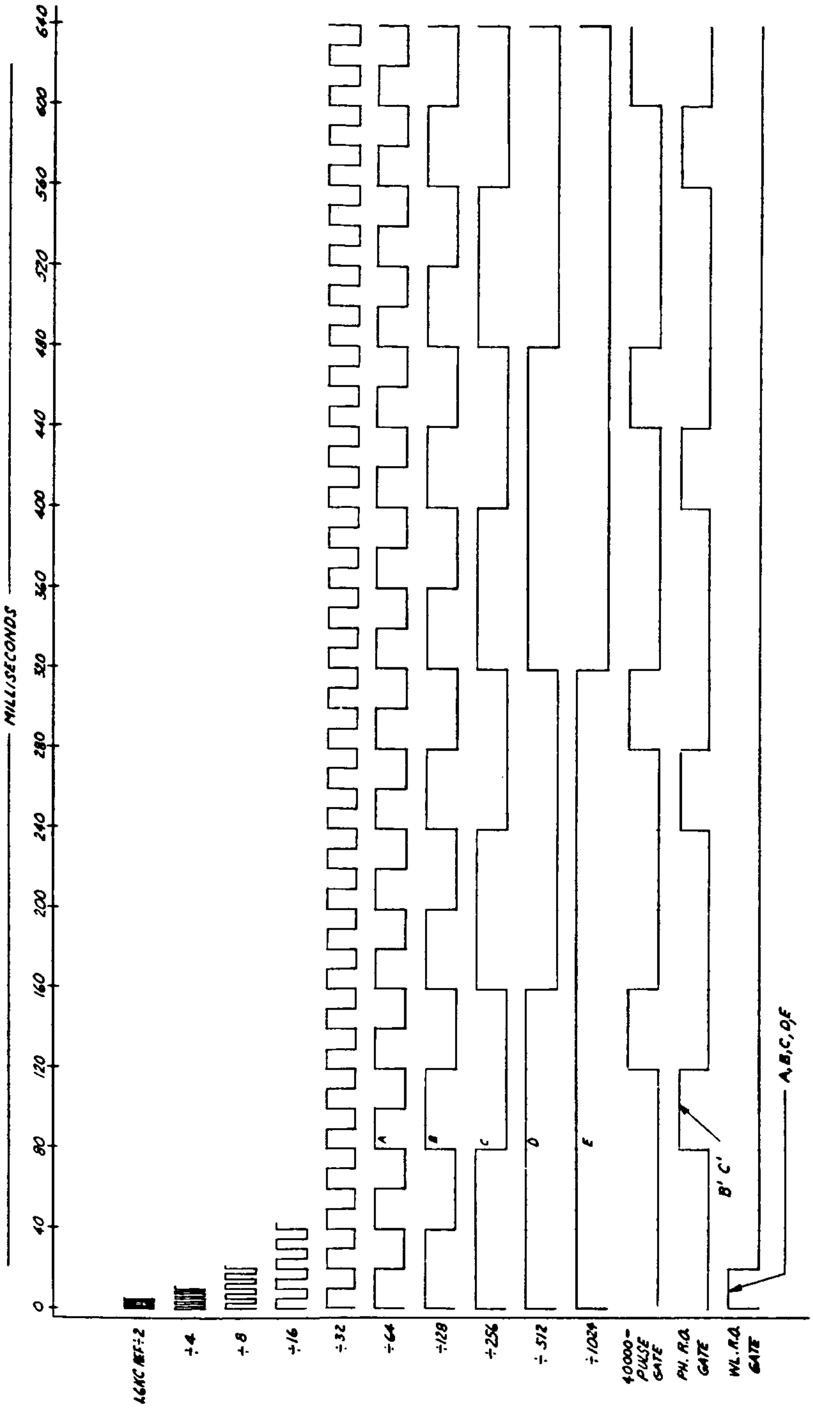

Figure 2.18 Timing Diagram Console S-57

3. XUV SPECTROPHOTOMETER FOR OGO-C/D SATELLITES

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3. XUV SPECTROPHOTOMETER FOR OGO-C/D SATELLITES

3.1 Introduction

In addition to the work done on the rocket monochromators and OSO satellite monochromators, electronics has been developed for another spectrophotometer to be orbited on the Orbiting Geophysical Observatory series of spacecraft (OGO-C and OGO-D). It is designated by NASA as Experiment 5020. This instrument does not require the accurate pointing of one minute of arc necessary for the rocket type monochromators. Mispointing up to a degree or so can be tolerated if corrections do not occur more frequently than every few seconds. This tolerance makes it possible for the instrument to be mounted on a solar paddle of the spacecraft and obtain adequate pointing.

The telemetry system is of the PCM type, with 3 different bit rates and many different main frame formats. This makes the electronics very sophisticated. However, the electronics problem has been solved successfully.

3.2 Object

Experiment 5020 has been designed to monitor radiation intensities in the extreme ultraviolet portion of the solar spectrum from 170 Angstroms to 1700 Angstroms. The spectrometer, with a practical resolving power, $\lambda/\Delta\lambda$, of approximately 100, cannot be expected to contribute any new information on the spectral details of solar emissions at these wavelengths. However, a calibrated instrument of this type is expected to provide much needed information on intensity levels and on temporal variations in these levels. Under conditions of precise solar pointing, the spectrommeter would scan the entire spectral range with a duty cycle of 100% except for times of choosing (by command) the use of the short scan modes (for special events). This would provide the most desirable type of measurement to allow an accurate and continuous correlation with various other solar observations and measurements of aeronomical parameters.

3.3 Description

The flight package consists of a scanning, grating spectrometer, two open-structure photomultipliers, associated pulse amplifiers, counters, power supplies, and logic circuitry. When the optic axis of the package is coincident with the mean solar vector, radiation from the entire solar disc will illuminate six gratings at a mean angle of incidence of 86° with an angular divergence of

32 minutes of arc. The six gratings (ruled in gold with 900, 1200, 1500, 1800, 2160 and 3600 lines/mm; ruled area 3 x 4 mm) are clamped together with parallel planes of dispersion and a common angle of incidence. The dispersed radiations are separated by a six-channel collimating slit system (resembling a Soller collimator). Each grating and associated collimator channel results in high transmission for a narrow spectral band. The collimator is driven mechanically in discrete steps. At each point of this step scan, the light transmitted by the collimator channels is intercepted by the six photocathodes located in two photomultipliers, three per multiplier. Anode pulses from each multiplier are amplified and counted simultaneously. The photocathodes are switched so that two channels of the six produce output signals; the complete record for any collimator position thus consists of a sequence of three readings; the timing is established by the experiment logic and general spacecraft functions.

Telemetered data include: 1) Coded information specifying the angular position of the mechanical scanning system, 2) Identification of the pair of photocathodes switched on, and 3) The number of counts accumulated from each photomultiplier. Comparison of the measured counting rates with laboratory calibrations allows an evaluation of the solar radiation flux incident on the aperture of the spectrometer.

A full spectral scan is achieved by a 12^{o} rotation of the collimator. This scan consists of 512 mechanical positions (3072 wavelength positions) and, at 4 kilobits, requires seven minutes in time. The spectral ranges scanned for the six gratings are as follows: 170-430 Å, 280-700 Å, 350-850 Å, 400-1000 Å, 500-1250 Å, and 660-1680 Å. As may be noted, these ranges overlap and some of the more intense solar emissions, such as lines at 1216 Å, 584 Å and 304 Å, are observed on more than one channel. This instrumental feature allows internal comparisons and checks for consistency among the various gratings, photocathodes and multipliers.

In addition to the 512-step spectral scan, the experiment may be directed by impulse command to execute short scans (37 steps) around any one of 32 chosen positions (wavelengths). The short scans require only 32 seconds in time and therefore permit a much improved observation of temporal variations of intensities in selected small portions of the six spectral subranges.

A photograph of complete package is given in Figure 3.1. The electronics package is on the left and the optics on the right. In front of the optics is one of the high voltage power supplies. The end of the other supply is visible between the optics and the electronics. Above the optics is the dual pulse amplifier.

3.4 Electronics

The electronics package consists of a frame holding five cards and a shielded chassis for a pulse amplifier. The system incorporates hybrid circuits of micro-modules and conventional circuits. For identification, the cards are named for their primary function. The package contains a Power Supply Card, a Format Control Card, a Collimator Control Card, a Photo-Cathode Control Card and a Counter Card. A photograph of the assembled package is shown in Figure 3.2. The individual cards are shown in Figure 3.3. The cards are interconnected by mother boards at each end of the stacked cards. The mother boards are shown in Figure 3.4. A block diagram of the system is shown in Figure 3.5.

3.4.1 The Dual Pulse Amplifier

The dual pulse amplifier takes the outputs from the two photomultipliers and amplifies these signals so that they can trigger the counters. A photograph of the unit is given in Figure 3.6. The two square blocks are high voltage filter networks. A schematic of the amplifiers is given in Figure 3.7. The amplifier has a gain of 2 volts per microampere and a rise time less than 50 nanoseconds.

3.4.2 The Counter Card

The counter card counts the number of anode pulses generated by the photomultipliers. The output pulses from the multipliers are amplified by the pulse amplifiers described above and fed to the input gates of the counters. These gates are controlled by the Format and Photocathode Cards.

The two photomultipliers each feed a 17 stage counter-shift register of which the 15 most significant bits are shifted out to the telemetry system. A schematic is shown in Figure 3.8.

3.4.3 The Format Control Card

The function of this card is to generate timing pulses to control the operation of the experiment. Its inputs from the spacecraft are the inhibit pulses (words) and the index pulses. The inhibit pulses in the main commutator mode are words 10, 11, 12, 25, 26 and 27. In the flexible format they are words 29 and 30. Other inputs to the Format Card originate on the Photocathode Card. They are the bit rate select signals (4 Kc, 16 Kc, or 64 Kc) and equipment group select.

The inhibit pulses originate in two equipment groups in the spacecraft, each operating as an independent system. The Format Card selects the inhibit pulse from one of the equipment groups, commanded by the switch signal, and this information produces the command information required for the rest of the system. A schematic of the Format Control Card is given in Figure 3.9.

3.4.4 Collimator Control Card

The sampling of discrete segments of the solar spectrum is accomplished by a collimator scanning the diffracted spectrum. The movement of this collimator is controlled and recorded by the Collimator Control Card.

Upon receipt of a command from the Format Card, the Collimator Card is interrogated. The stored data, consisting of collimator position and commands from the "ground" determine the direction the collimator will step.

The collimator normally scans 512 positions, being commanded to reverse at the 0 and 512th position. However, upon command from the "ground" the collimator may short scan 37 of the 512 steps. There are a total of 31 of these short scans selected by "ground command."

Other timing pulses from the Format Card command the stored data to be shifted out to the telemetry system via the Photo-Cathode Card. A schematic of the Collimator Control Card is given in Figure 3.10.

3.4.5 The Photo-Cathode Card

The Photo-Cathode Card is the catch-all card in the system. It contains the output data drivers and logic for equipment groups bit rate selection, photo-cathote switching and shift pulse selection.

The inputs to the Photo-Cathode Card from the spacecraft are a switch signal, mode signal, bit rate signal, and the shift pulses from both equipment groups. The card also receives timing pulses from the Format Control Card and data from the Collimator Card and Counter Card. The switch signal input selects the information coming from one of the two equipment groups. The mode signal indicates whether the selected equipment group is operating in the real time mode or the record mode. The real time equipment group may operate in one of 3 bit rates, 4 Kc, 16 Kc, or 64 Kc whereas the equipment group operating in the record mode operates at 4 Kc. The combination of mode and bit rate signal determines the frequency at which the experiment is to operate.

A schematic of the Photo-Cathode Card is shown in Figure 3.11.

3.4.6 Power Supply Card

The Power Supply Card converts the nominal 28 volt input to six output voltages, -2 volts, +4 volts, +6 volts, -20 volts, +20 volts and +100 volts. The prime function of the -2 volt, +4 volt and +6 volt outputs is to supply the logic power. The -20 volt and +20 volt outputs are used in the photomultiplier and to bias the aperture grids. The +20 volt output also drives the collimator stepping motor. The +100 volt output supplies the cutoff bias for the photo-cathodes in the photomultiplier.

Also on the card is the logic to control the power stand by function which activates the system in sunlight, and the impulse command relays used for ground control of the collimator.

A schematic of the sun detection power control is given in Figure 3.12. The power converters were supplied by Astronetic Research, Inc. of Nashua, New Hampshire.

3.5 Output Data

The output data for the complete experiment consists of two 27 bit data groups. Both groups contain the same type of information, as follows:

bits 1 through 9 indicate collimator position

bit 10 indicates the photomultiplier for which bits 11 through 27 contain data

bits 11 and 12 indicate the photo-cathodes and bits 13 through 27 represent the data accumulated by the counter.

3.6 Test Equipment

The OGO electronics requires enabling signals for operation. As stated above these signals will be supplied by the spacecraft when the experiment is installed on the spacecraft. At all other times these signals are supplied from a test console containing a spacecraft simulator. This simulator generates all the signals that the spacecraft normally supplies to the experiment. It also provides facilities for commanding the experiment and for stimulating the experiment to check for proper operation.

Photographs of the test console are given in Figures 3.13 and 3.14.

In addition to the test console, a Ground Support Equipment Console (GSE) has been developed. This unit is used when the experiment is mounted on the spacecraft to supply stimuli to the experiment.

3.7 Flight Operations

Adcole Corporation has built electronics for four spectrophotometers, a prototype and three flight models.

All units have been environmentally tested at Goddard Space Flight Center and calibrated at the AFCRL laboratory.

One flight unit has been installed on the OGO-C spacecraft at Space Technology Laboratories in California.

The present schedule calls for launch of the OGO-C satellite in 1965 and the OGO-D in 1966.

3.8 List of Figures

Figure

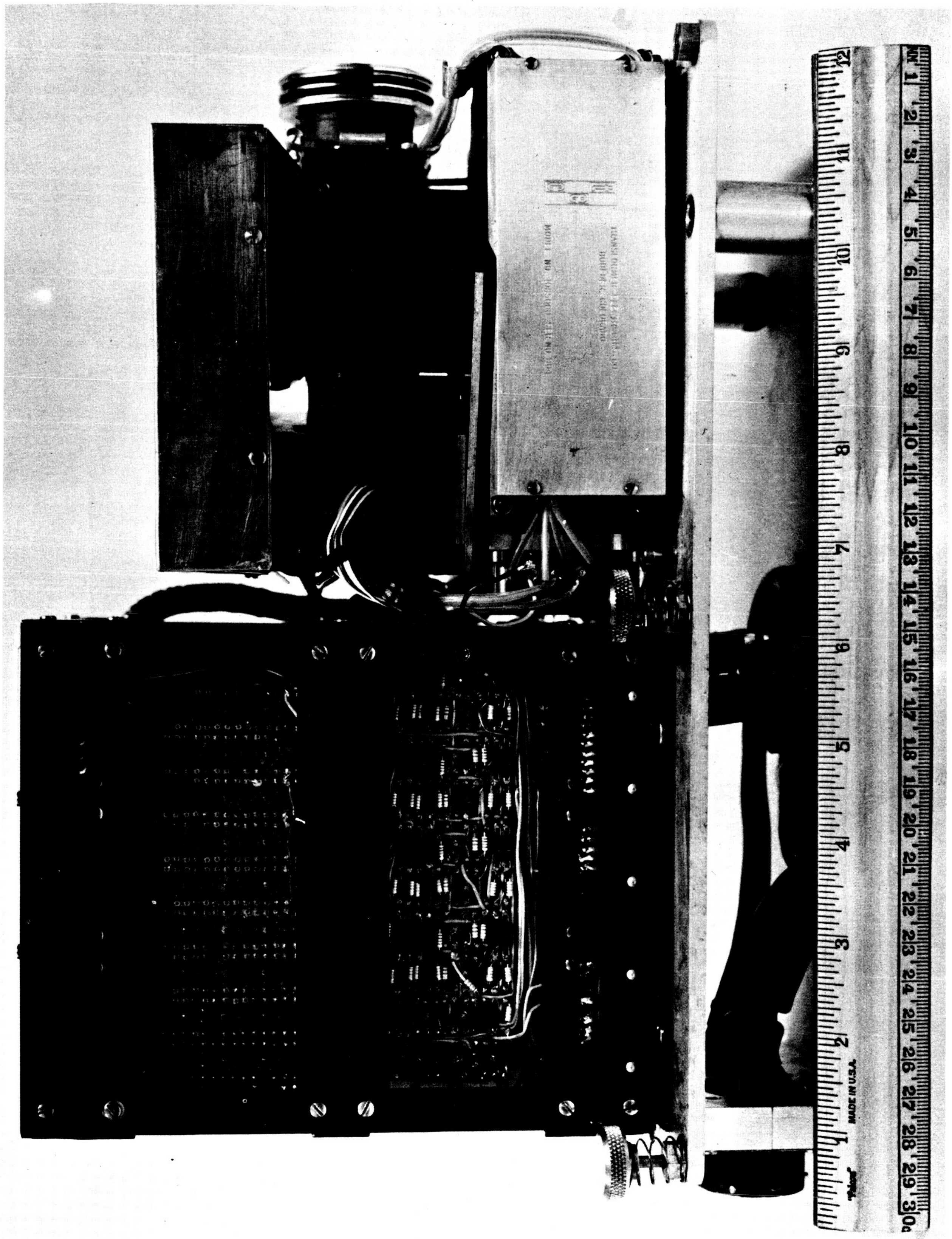


Figure 3.1 OGO Spectrophotometer

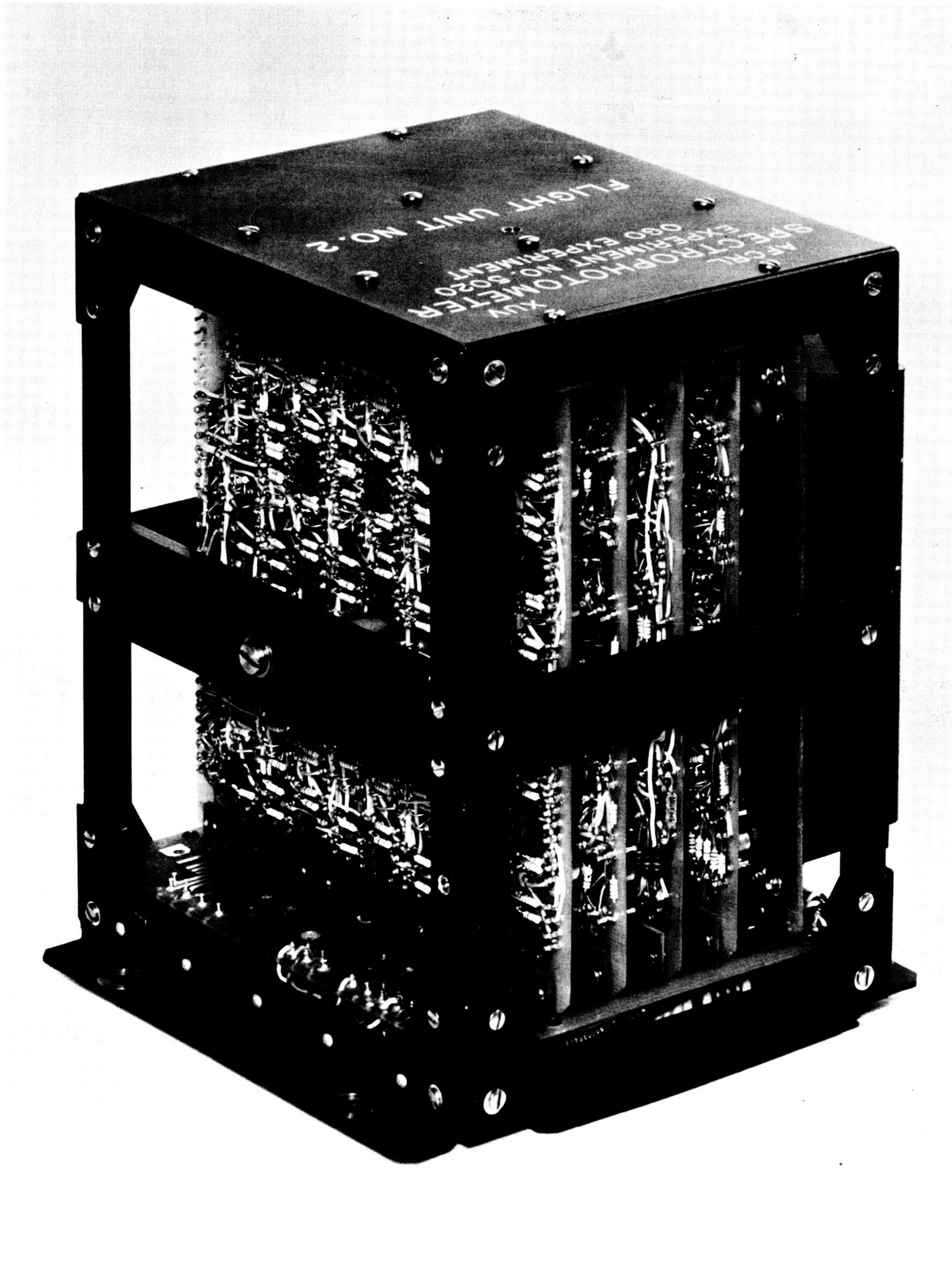


Figure 3.2 OGO Electronics Package

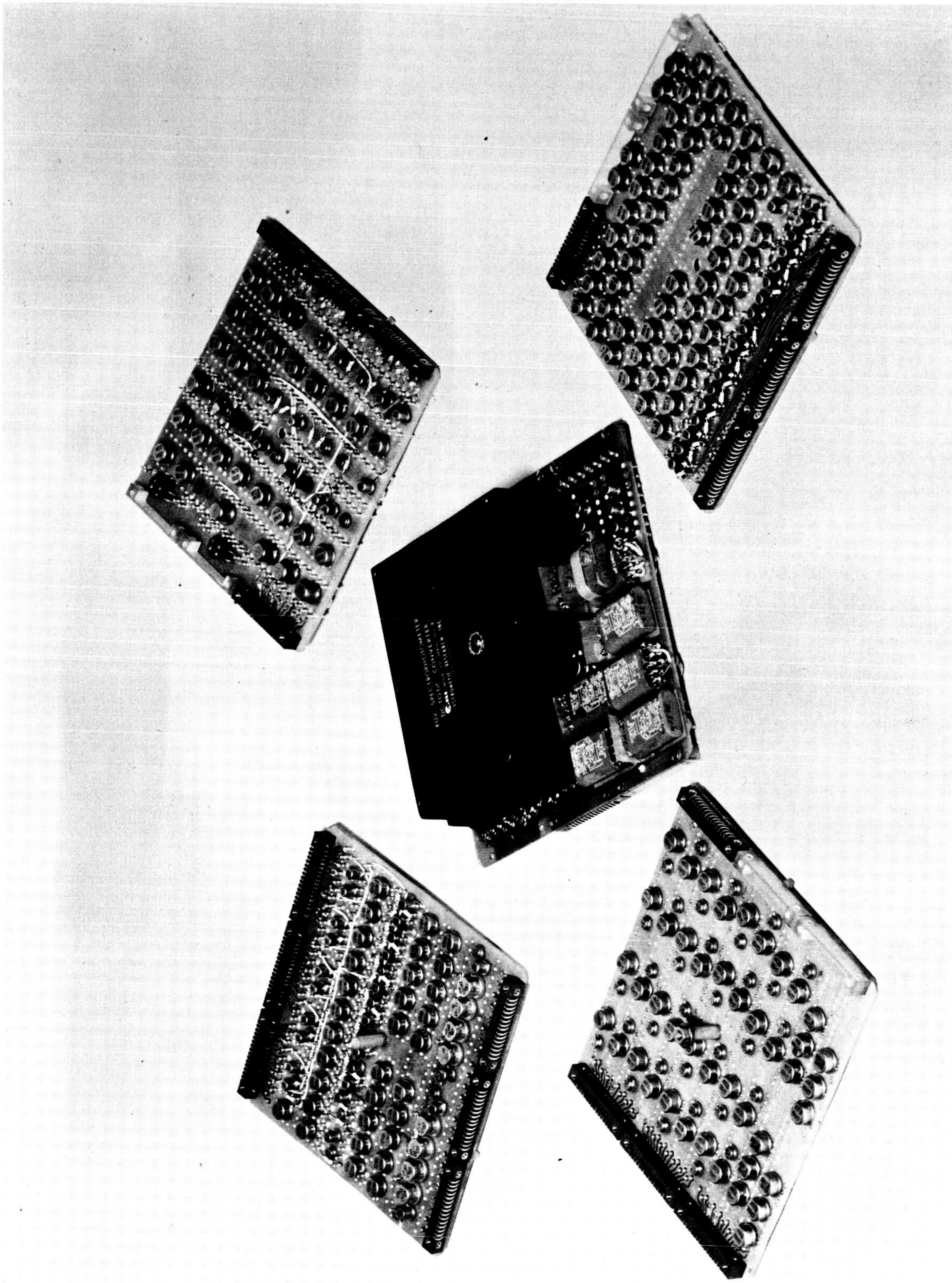


Figure 3.3 OGO Electronics Cards

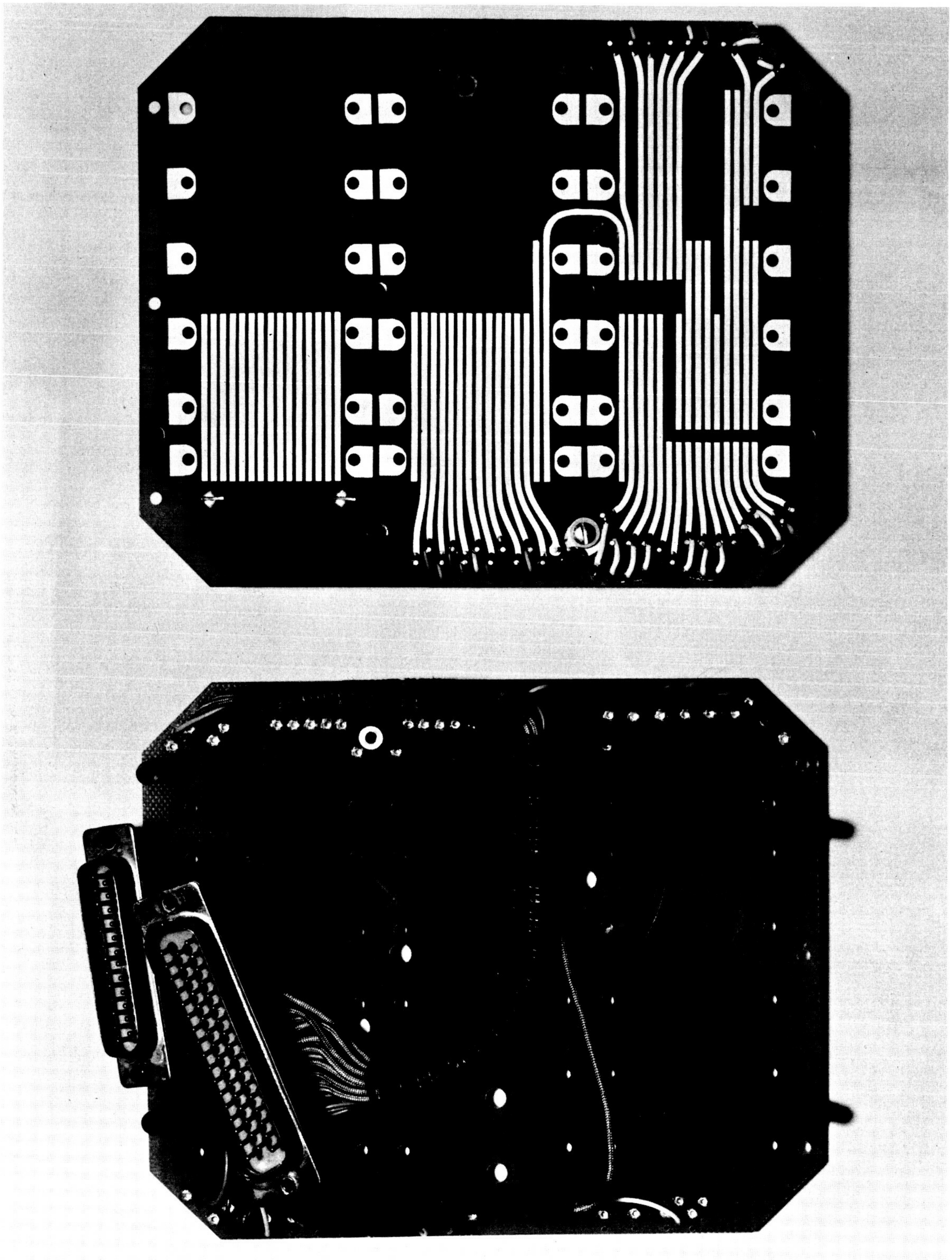


Figure 3.4 OGO Mother Boards

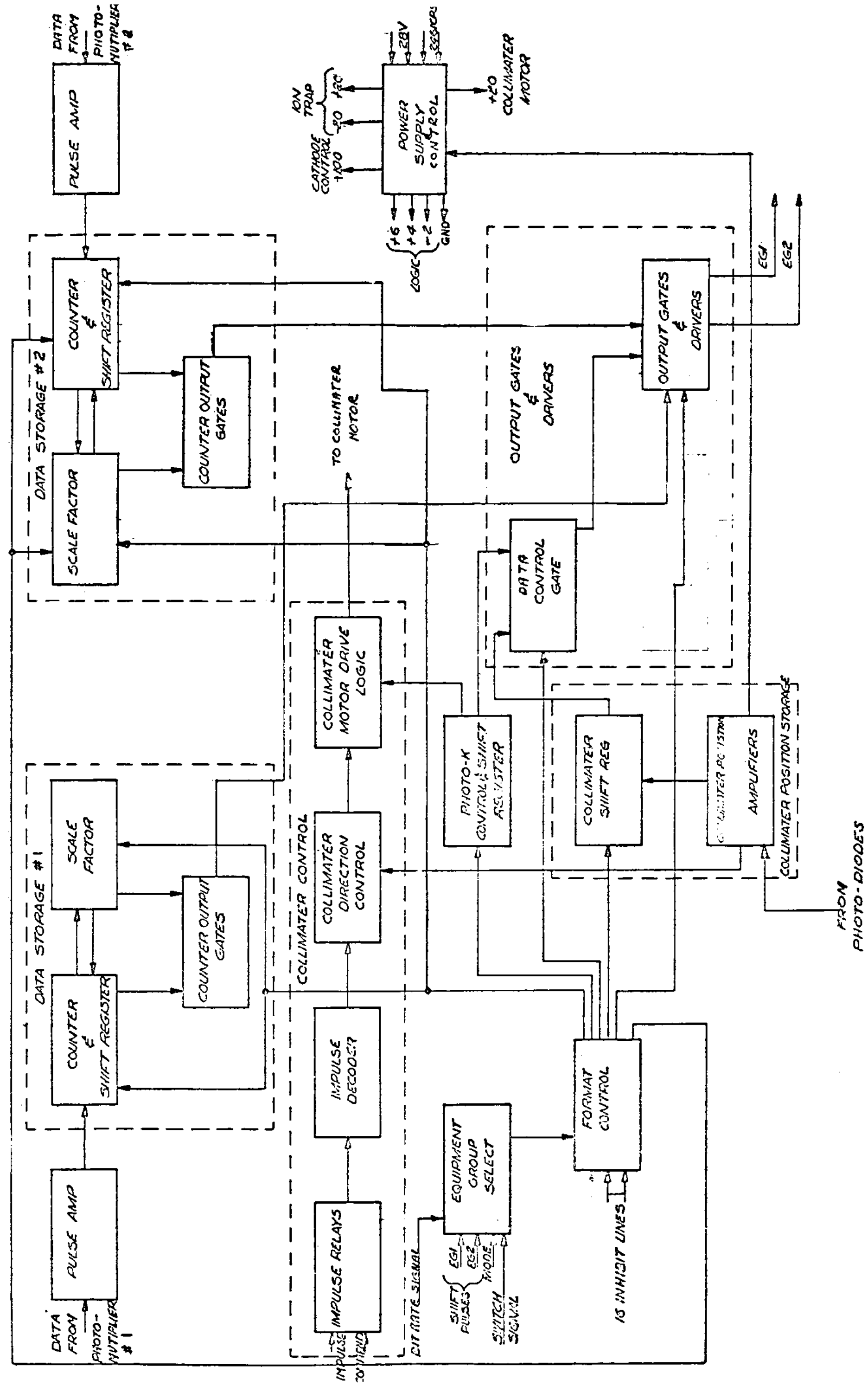


Figure 3.5 OGO XUV Scanning Spectrophotometer

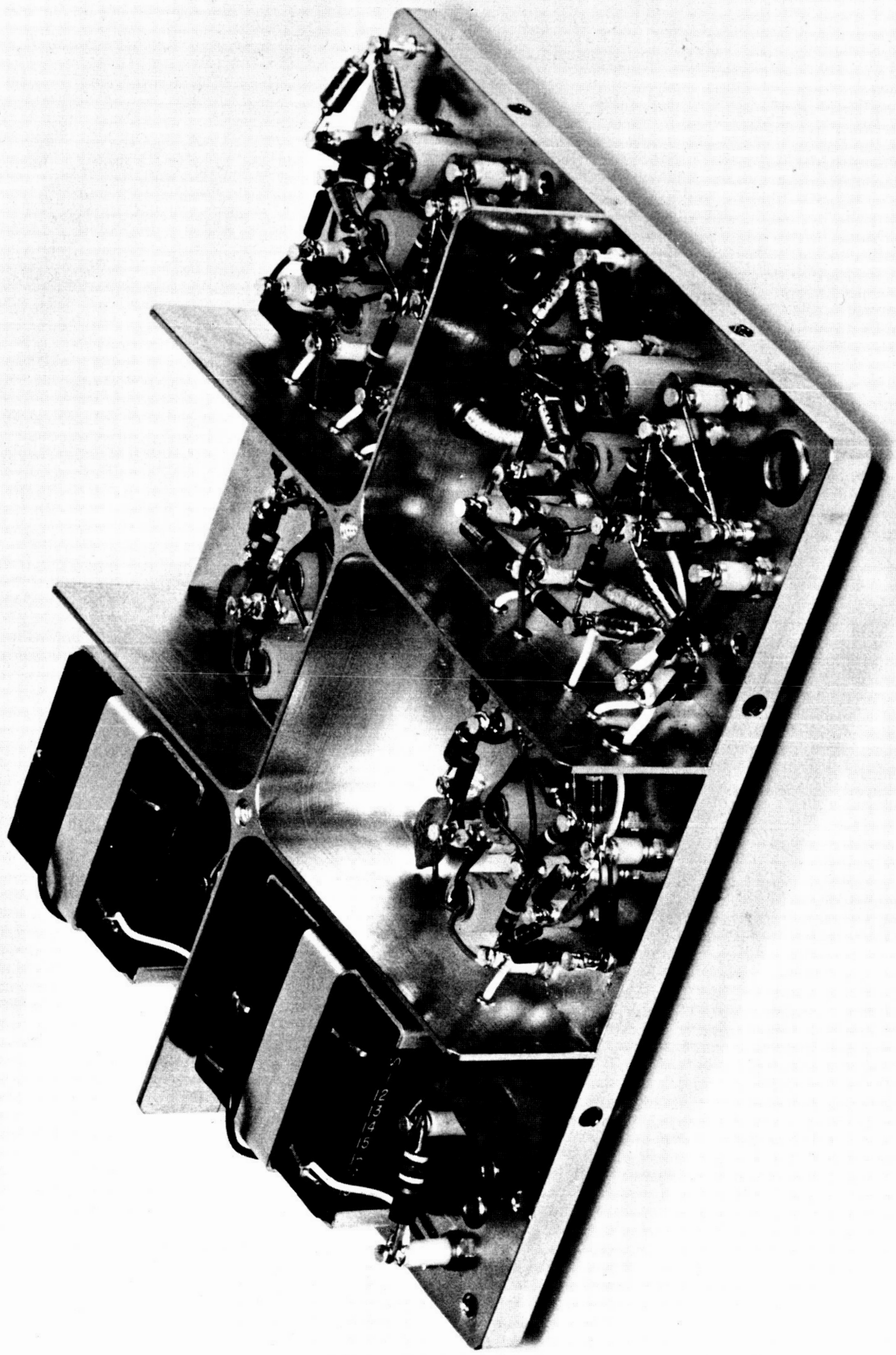


Figure 3.6 OGO Dual Pulse Amplifier

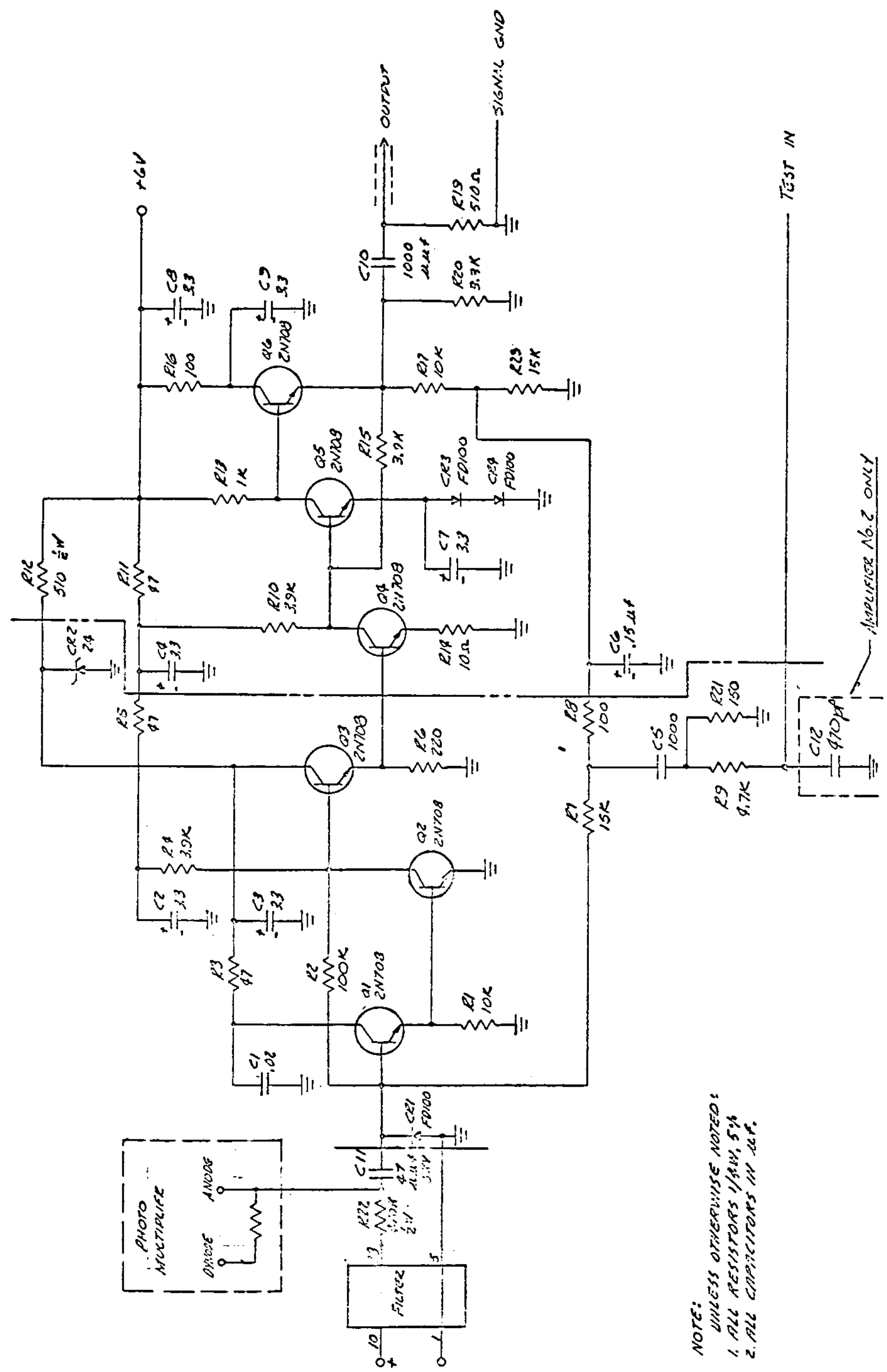


Figure 3.7 Schematic - Pulse Amplifiers Nos. 1 & 2

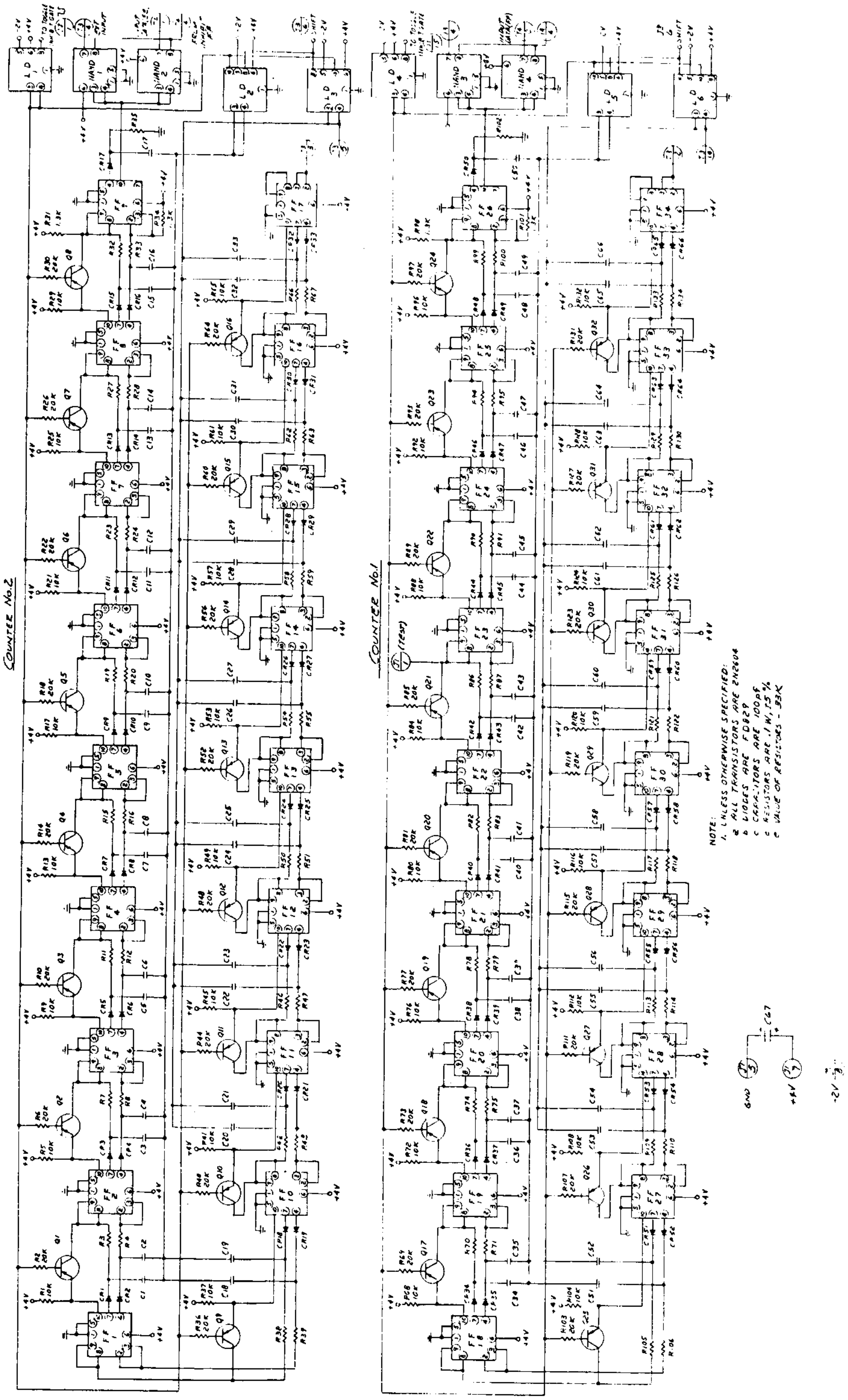


Figure 3.8 Schematic - Counters & Shift Registers Spectrophotometer

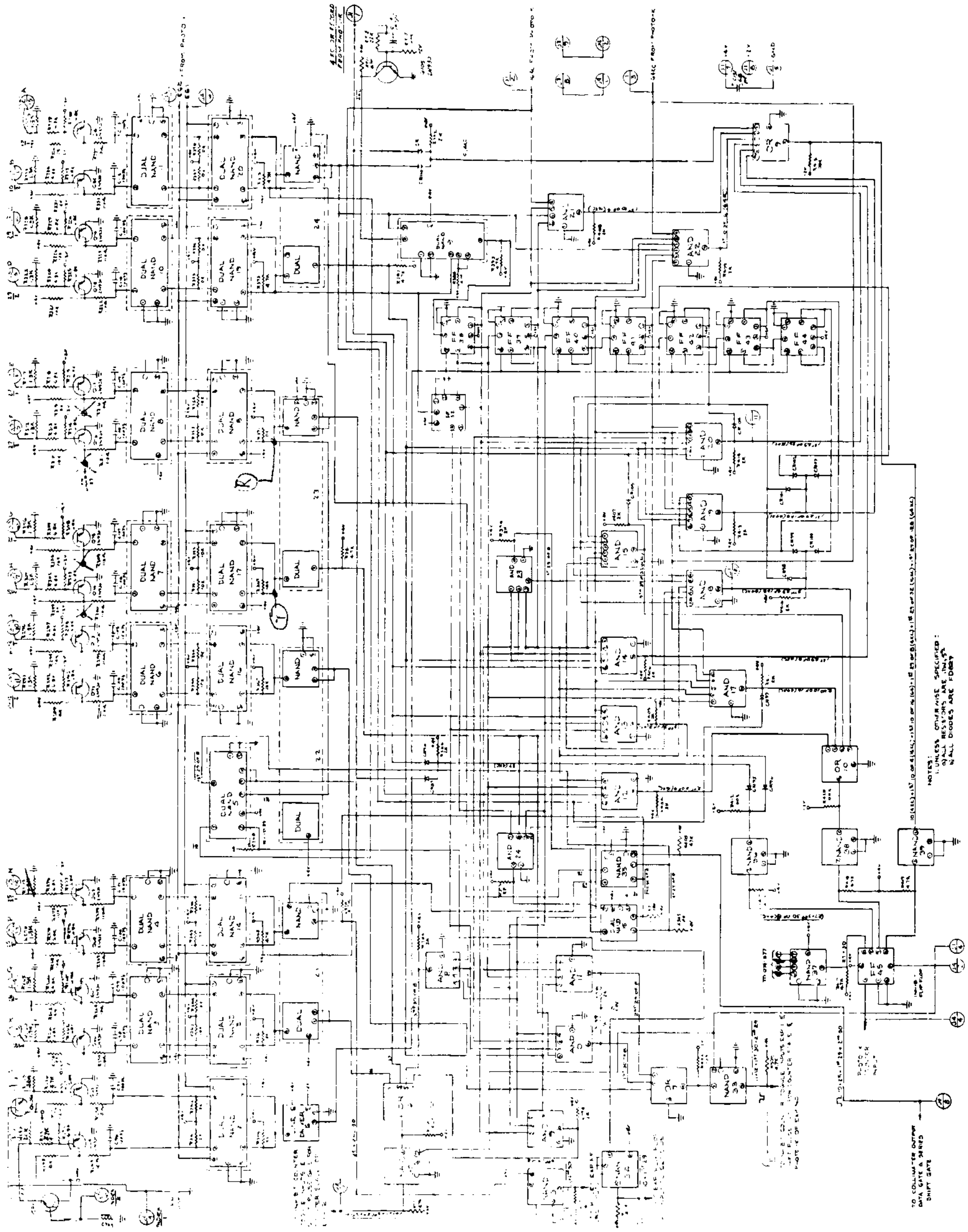


Figure 3.9 Format Control

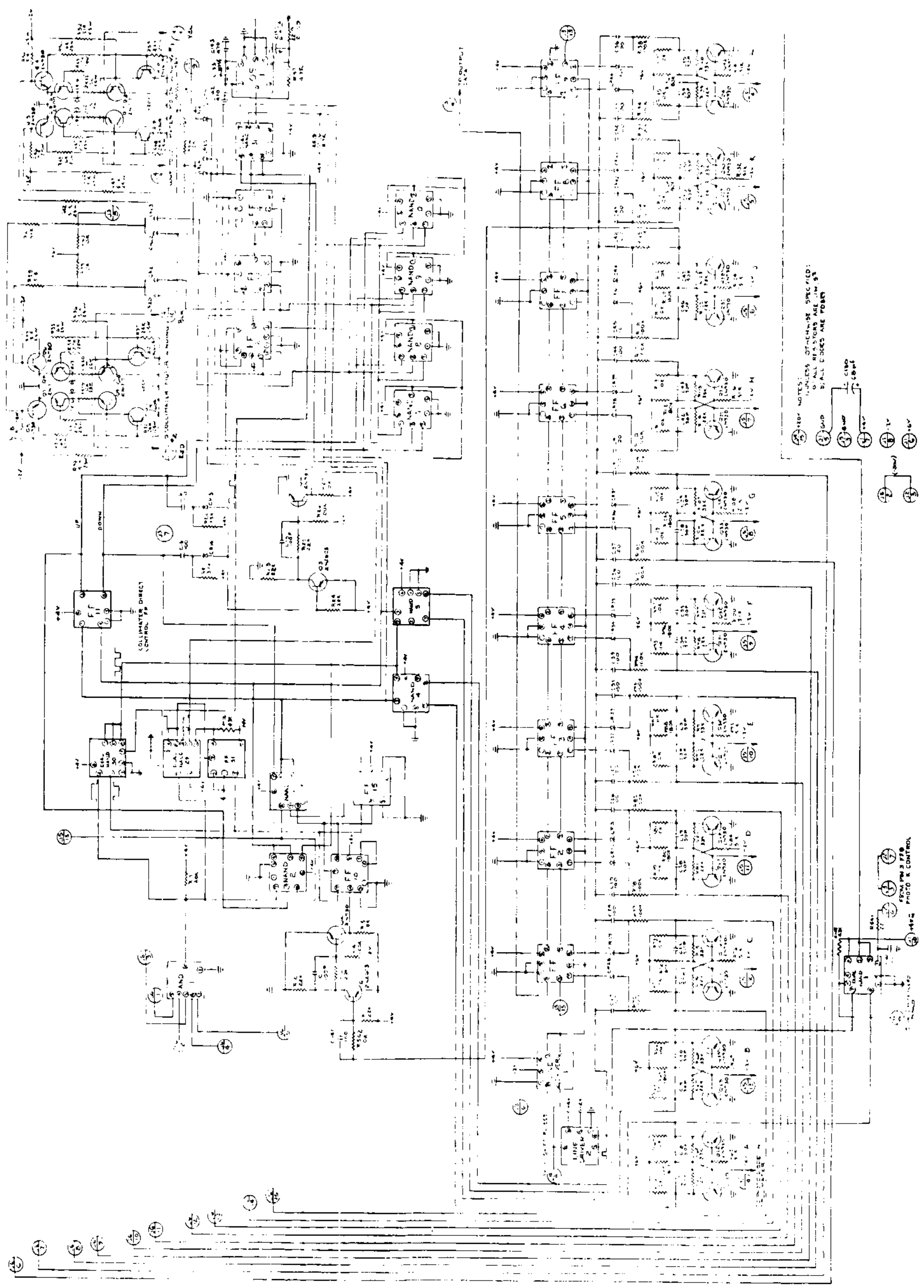


Figure 3.10 Collimator Control

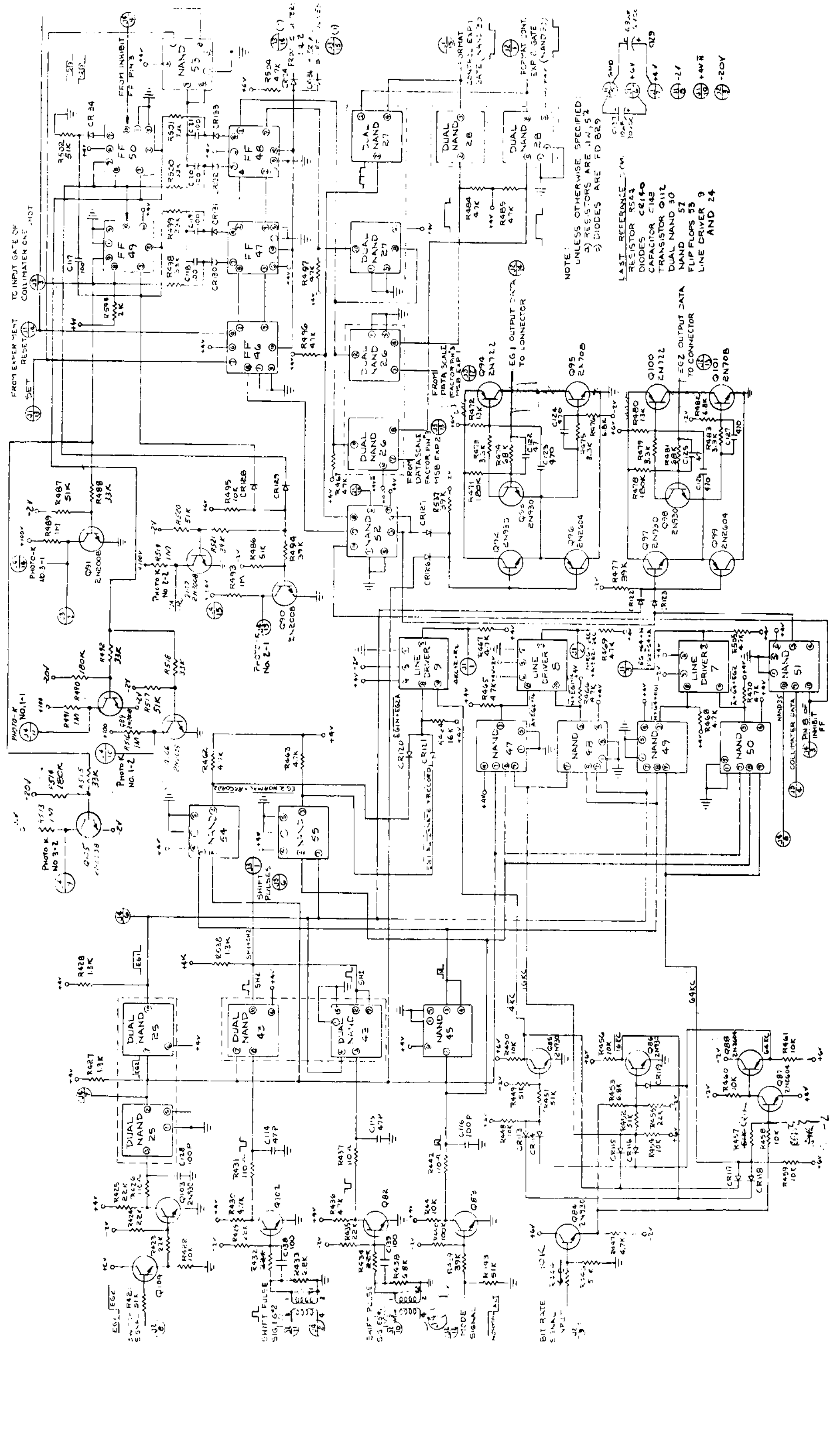


Figure 3.11 Photo-K Control and Select Shift (EG) Output Gates and Drivers

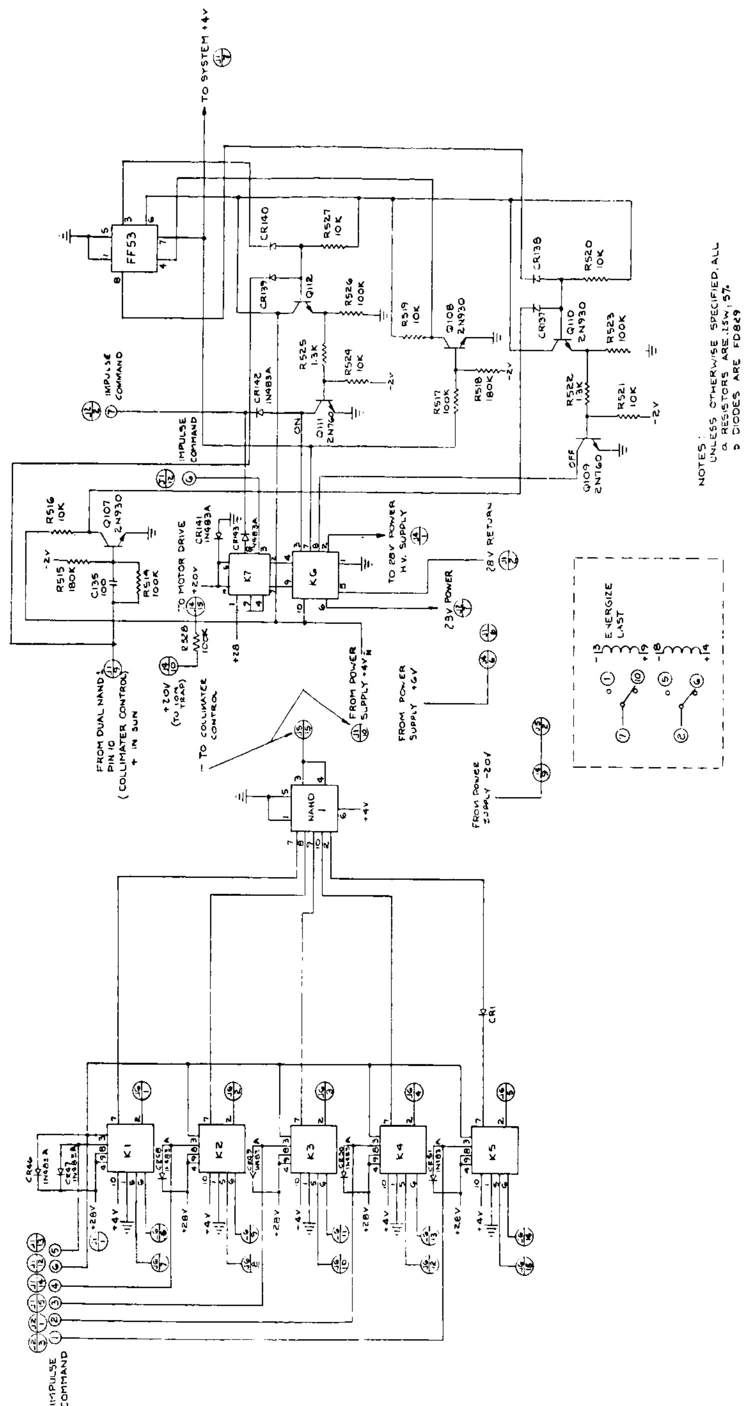


Figure 3.12 Sun Detection Power Control on Power Supply Card

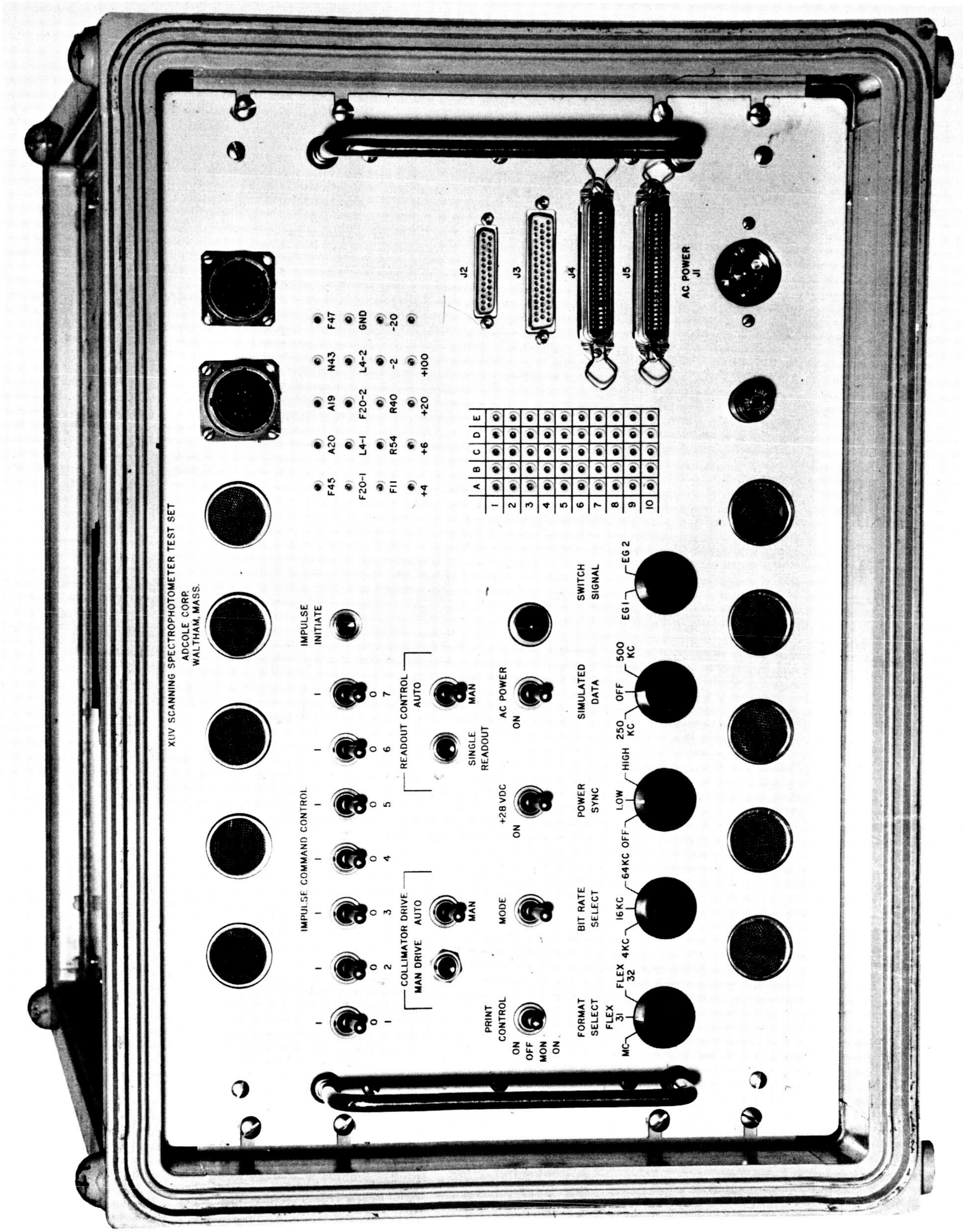


Figure 3.13 OGO Test Console-Front View

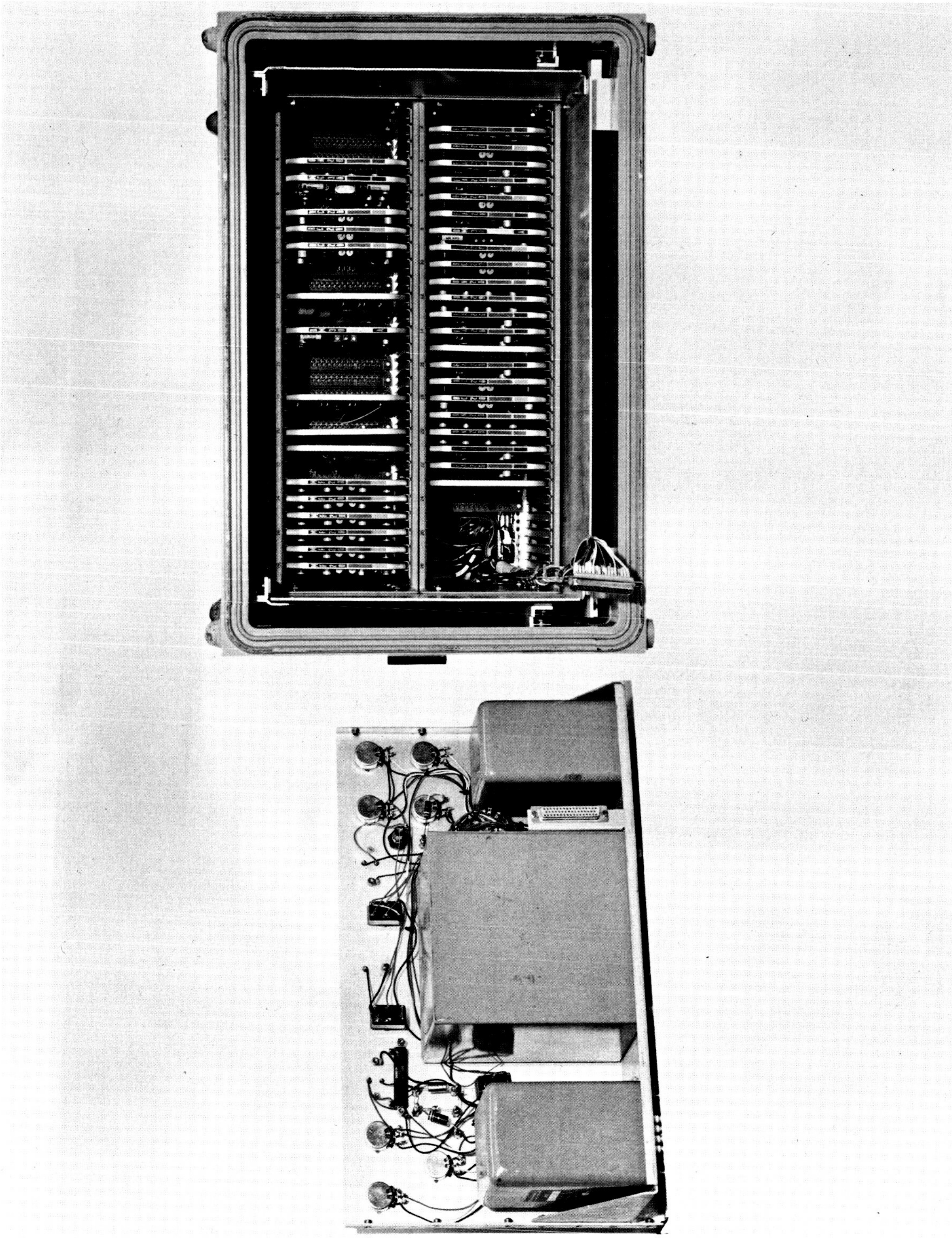


Figure 3.14 OGO Test Console-Rear View

4. RETARDING POTENTIAL ANALYZER

CONTENTS

4. RETARDING POTENTIAL ANALYZER

4.1 Introduction

Retarding Potential Analyzers have been flown as secondary experiments on almost all of the Monochromator Aerobee shots. The retarding potential analyzer can be used to measure both ion and electron density and energy and also solar EUV radiation. During the period covered by this report successful measurements of electron energy or temperature at various altitudes have been made by instruments mounted on the EUV Monochromators flown from White Sands, New Mexico. Some information on electron density has also been obtained from the Aerobee instruments.

A retarding potential analyzer programmed to operate in all these modes was orbited on the Air Force Research Satellite for Geophysics in June 1963. The equipment itself was constructed on the previous Air Force contract. This satellite also carried a solar aspect system built by Adcole Corporation on the previous contract. Both the aspect system and the retarding potential analyzer performed correctly. A picture of the satellite with shroud removed is shown in Figure 4.1. The inch scale is resting on the detector. On the panel below the detector is the program box. The panel above the detector mounts a solid state commutator also built by Adcole Corporation. Two of the four solar aspect detectors are shown on brackets projecting from the right end of the satellite.

4.2 Description of the Electron Retarding Potential Analyzer

The complete Electron Retarding Potential Analyzer consists of a planar detector and electronics to control its voltages and amplify the output signal and convert it to the correct form for telemetry.

The output from the detector is a negative current in the range between 10^{-9} and 10^{-6} amperes. This current is amplified in a feedback amplifier with a logarithmic gain characteristic to produce a 10 volt output change. The output is divided by 2 and time shared with calibration voltages and fed to the telemetry. A grid on the detector is swept with a linear triangular waveform to produce the retardation of the electrons. A block diagram of the system is shown in Figure 4.2. A picture of the complete Retarding Potential Analyzer is shown in Figure 4.3. The detector is shown mounted on the electrometer amplifier and the remainder of the electronics is shown on the upper left side of the monochromator casting. The electronics with the cover removed is shown in Figure 4.4.

4.2.1 Detector

The detector is a planar structure consisting of a disc-like cathode or target, a retarding grid assembly spaced about 1/4 inch above the cathode, and a top aperture plate with an input aperture which also has a grid across it. When the detector is to be used to detect EUV radiation by the process of photons driving off photo-electrons from the tungsten cathode, another grid is added between the retarding grid and aperture grid to collect these electrons. A schematic of the detector is given in Figure 4.5. With the aid of measurements made in the laboratory with special electronics built for the purpose and from flight data, several modifications have been made to the original detectors. A discharge ring has been added around the cathode to prevent charge build up. The retarding grid has been made a double grid to give a better equipotential plane. A new aperture has been added above the aperture plate to collect secondary electrons emitted from the aperture plate. A new grid at the aperture voltage has been added over the complete top. As mentioned above, the work necessary to calibrate and improve the detectors has required test equipment with flexible parameters. A laboratory test set was made by Adcole Corporation which supplied the necessary adjustable voltages, sweep voltages and amplification to carry out the program. In addition, the console for the electron gun used as a source was also made by Adcole Corporation.

The design, construction and modification of the detectors has been done by Comstock and Wescott, Inc., Cambridge, Massachusetts. The various detectors have been given different model numbers by Comstock and Wescott, Inc. The original electron or ion detector was MRPA-3. When the retarding grid was changed to a double structure the number was changed to MRPA-4. With the addition of the assembly to capture the secondary electrons the number became MRPA-4A. A small modification was then made in the geometry of the aperture to minimize edge effects and this detector was designated MRPA-4B.

4.2.2 Electrometer Amplifier

The electrometer amplifier is used to detect the small currents from the detector and produce a corresponding voltage change which can be telemetered to the ground during flight.

It is a feedback amplifier the gain of which is controlled by the value of feedback resistor R_{fb} and the gain of the active beta network. Refer to Figure 4.2. The gain of the active beta network is changed versus input signal amplitude to give a gain characteristic made of a series of straight lines of different slopes to produce a logarithmic gain curve.

This logarithmic characteristic is necessary because of the large dynamic range of the input signal. Also it aids in the data reduction, since the detector output current theoretically changes logarithmically with retarding voltage, thus producing a straight line when plotted on semi-log paper versus retarding voltage.

The amplifier as originally designed used Raytheon CK-587 electrometer tubes. These tubes performed adequately, but only if many precautions were taken. The tubes had to be aged and matched. A regulated filament supply was necessary, and they are microphonic. However, data was obtained on 3 flights in 1963 and early 1964 with this arrangement. A schematic is shown in Figure 4.6.

With availability of field effect transistors in 1964, the electrometer amplifier was redesigned to use them in place of the electrometer tubes. The schematic of the new amplifier is shown in Figure 4.7. This amplifier was first flown in December 1964.

4.2.3 Beta Amplifier

As stated in the previous section, the beta circuitry must have different gains at different input levels to produce the desired logarithmic characteristic in the overall amplifier. This is accomplished by again using a feedback amplifier (operational amplifier). The equivalent R1 and R2 of the operational amplifier are changed by diode breakdown at the correct levels to produce the required gains. A schematic of the beta amplifier is shown in Figure 4.8.

The gain is varied in seven steps between 0.2 and 20. The break voltages and gains are given in the table on the schematic. A typical calibration curve of the overall amplifier is given in Figure 4.9.

4.2.4 Sweep Generator

The retarding grid sweep voltage is generated by the sweep generator card. A schematic is shown in Figure 4.10. An amplifier with capacitive feedback is used to make a linear sweep. The limits are set by unijunction thresholds which control a diode switch to reverse the sweep direction.

4.2.5 Calibration Card

The calibration card inserts zero, half scale and full scale calibration voltages onto the amplifier output at the end of each positive going sweep period. This is accomplished by a solid state commutator. The commutator is controlled by the outputs of two flip-flops triggered four times only by a unijunction oscillator. A schematic is shown in Figure 4.11.

4.2.6 Power Supply

The power supply produces +70 volts, +35 volts, and -25 volts from the 26 - 30 volt monochromator silver zinc battery. A schematic is shown in Figure 4.12. The battery voltage is changed to about 23.5 volts to produce a constant output from a secondary winding of the dc-dc converter. The individual secondary outputs are then series regulated, using selected temperature stable zener diodes for reference.

4.3 Modifications

For the December 8, 1964 firing, the retarding potential analyzer was modified to change the voltages on the detector on alternate sweeps to make the RPA into a Langmuir type probe. This was accomplished by adding a new circuit board to the electronic assembly. For the Langmuir mode of operation, the aperture plate is tied to the retarding grid and swept along with it.

4.4 Calibration

A calibrated source of electrons at the proper energy levels is not available in the laboratory. Therefore, an actual overall calibration cannot be performed. What is done is the following: The electronics is calibrated separately, giving a curve as in Figure 4.9. The detector is then installed and the complete instrument is placed in a vacuum tank outfitted with an electron gun aimed to produce secondary electrons that can be measured by the RPA. If the output varies in such a way as to indicate retardation, the equipment is considered operable.

4.5 Chronology

Table 4.1 is a chronological listing of flight experiments performed with the retarding potential analyzer. All instruments were attached to rocket monochromator castings and flown with them from White Sands. The RPA instrument number is the same as the rocket monochromator number.

4.6 Flight Operations

The retarding potential analyzers (with the exception of the equipment on the Air Force satellite) were each mounted on a rocket monochromator casting and flown along with it on an Aerobee-150 vehicle from White Sands Missile Range, New Mexico.

Table 4.1

RETARDING POTENTIAL ANALYZER

DATE	INSTRUMENT	DETECTOR TYPE	AMPLIFIER TYPE	REMARKS
2 May 1963	#17	MRPA - 4	Electrometer tube	Good data
10 July 1963	#18	MRPA - 4	Electrometer tube	No data - no input from detector
12 December 1963	#19	MRPA - 4	Electrometer tube	Good data
30 March 1964	#22	MRPA - 4A	Electrometer tube	Good data
8 December 1964	#25	MRPA - 4B	FET	Good data

The rocket monochromator console described in Section 1 has a position to monitor the RPA output while the instrument is in the tower.

The RPA output is fed to the 10.5 kilocycle channel of the FM-FM telemetry on the rocket. The sweep voltage is sampled three times a second by the solid state commutator used with the monochromator. The power supply voltages are also monitored every second by the same commutator.

The instrument is turned on before lift-off and is left on through lift-off and for the complete flight. Data is acquired after the nose cone is ejected at about +100 seconds until about +425 seconds on a typical firing. A description of the flights is given below.

RPA #17 2 March 1963

RPA #17 with the MRPA-4 detector was mounted on RM #17 casting and flown at 10:00 AM, 2 March 1963 on an Aerobee-150 vehicle. It reached an altitude of 145 miles. The object was to measure electron temperature. Good data was obtained and reduced by Adcole Corporation.

RPA #18 10 July 1963

A similar instrument was fired on 10 July 1963. No data was obtained, as the output of the instrument did not move. All electronic monitors registered correctly so it is assumed that the output from the detector did not reach the electronics or else the detector failed to function.

RPA #19 12 December 1963

The detector on RPA #19 was a model MRPA-4A. This detector has the grid added in front of the aperture plate to collect secondary electrons emitted by the aperture plate and prevent them from getting into the aperture and being measured. Good electron temperature data was obtained and again reduced by Adcole Corporation.

RPA #22 30 March 1964

The MRPA-4A detector was again used on this flight. Good data was obtained and reduced by Adcole Corporation.

RPA #25 8 December 1964

This instrument used the MRPA-4B detector. It also used, for the first time, the electrometer amplifier with field effect transistors. Good data was obtained. This instrument was also the first to operate as a Langmuir probe in addition to a retarding potential analyzer.

4.7 Data Reduction

The object of the experiment is to measure the electron temperature at various altitudes in the upper atmosphere. Electrons are collected by the detector cathode after they have passed through the aperture grid and the retarding grid. As the retarding grid is swept from positive to negative, more and more of the electrons are retarded and do not reach the cathode. Thus the current measured decreases from the saturated value, where hopefully all the electrons in the space directly above the aperture are collected, to zero current when all the electrons are retarded. The actual expression for this current change is:

$$I = I_o \epsilon^{-\frac{eV}{kT}}$$

where I is the cathode current

I_o is the saturation current

e is the charge on the electron (1.6×10^{-19})

V is the voltage on the retarding grid

k is Boltzman's Constant (1.37×10^{-23})

and t is the temperature in degrees Kelvin

ϵ is Naperian base of logarithms then $\quad \ln I = \dfrac{e\ V}{k\ T}$

and $\quad \Delta \ln I = \dfrac{e\ V}{k\ T}$

if I changes by $\frac{1}{\epsilon}$ then $\Delta \ln I = 1$

and

$$\frac{e\ V}{k\ T} = 1$$

$$T = \frac{e\ V}{k} = \frac{1.6 \times 10^{-19}}{1.37 \times 10^{-23}} \quad \Delta V$$

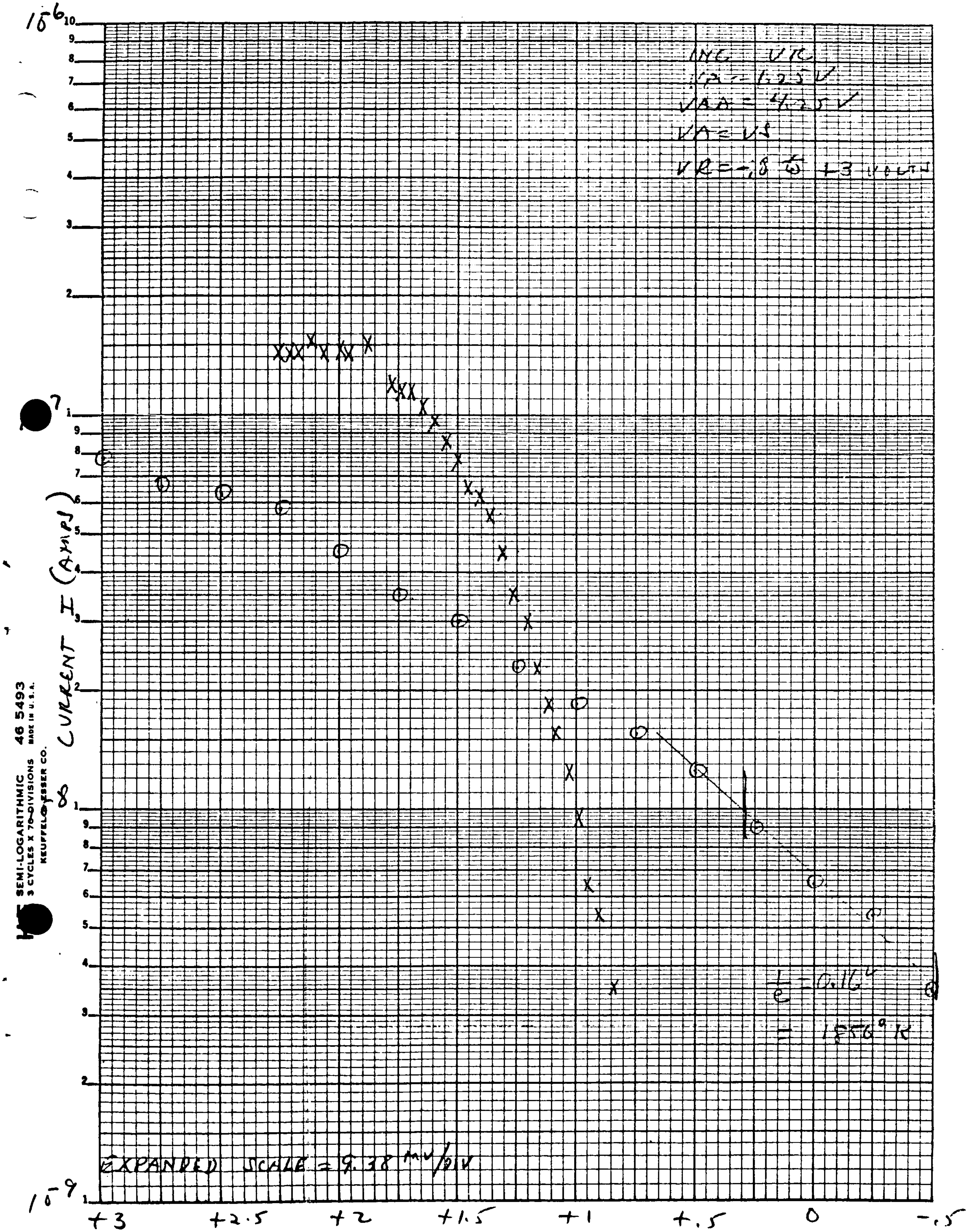
or $T = 11600^{\circ}K$ per volt required to change I by $\frac{1}{\epsilon}$ or a ratio of 1 to 0.37.

The electron temperature is derived from the paper record in the following manner. The raw data is in the form of output voltage plotted versus time on Data-Rite paper rolls at 10 inches per second. Sweep voltage sampled every one-third of a second is also given on the commutator output channel on the same paper.

The output voltage is read from the paper at small sweep voltage increments and converted to current using the calibration curve. These values of current are plotted on semi-log paper versus their corresponding value of sweep voltage. If proper operation of the instrument was obtained, the plot at low currents should be linear on this semi-log paper. A sample plot is given on the next page. The currents versus voltage have been plotted with two different voltage scales to give the overall picture and to give an expanded scale so that the voltage change for a $\frac{1}{\epsilon}$ current change can be derived. This particular example gave a 0.16 volt change for $\frac{1}{\epsilon}$ current change. This gives a temperature of about 1850 degrees Kelvin at the particular altitude at which this measurement was taken.

The above procedure is used for each retarding sweep over the complete flight. Since the sweeps require 5 seconds and the flight duration for data is about 325 seconds, about 65 plots must be done. This work has been done by Adcole Corporation.

RPA (MODE I) MONO 4.27 344 SECS



4.8 List of Figures

Figure

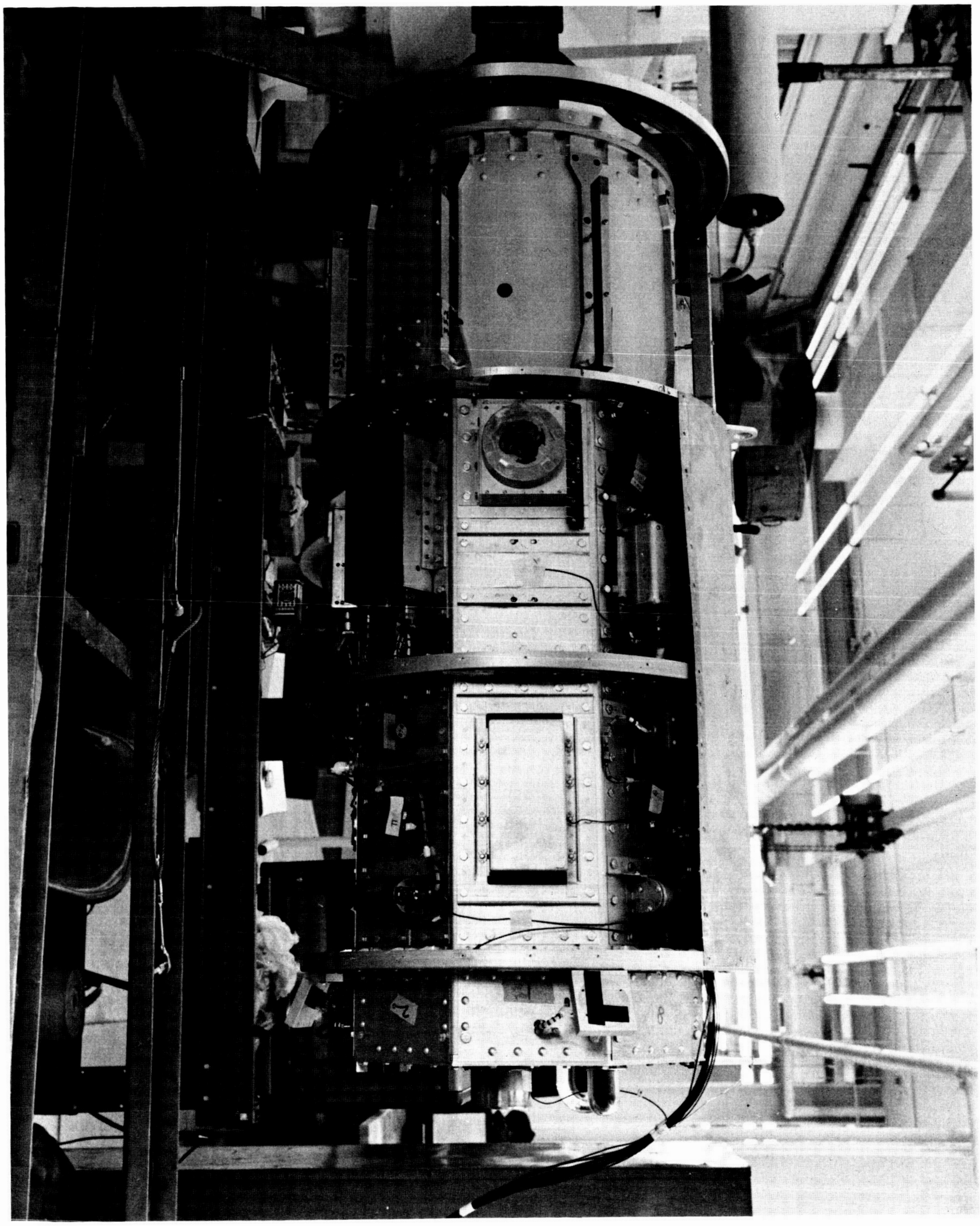


Figure 4.1 Air Force Satellite

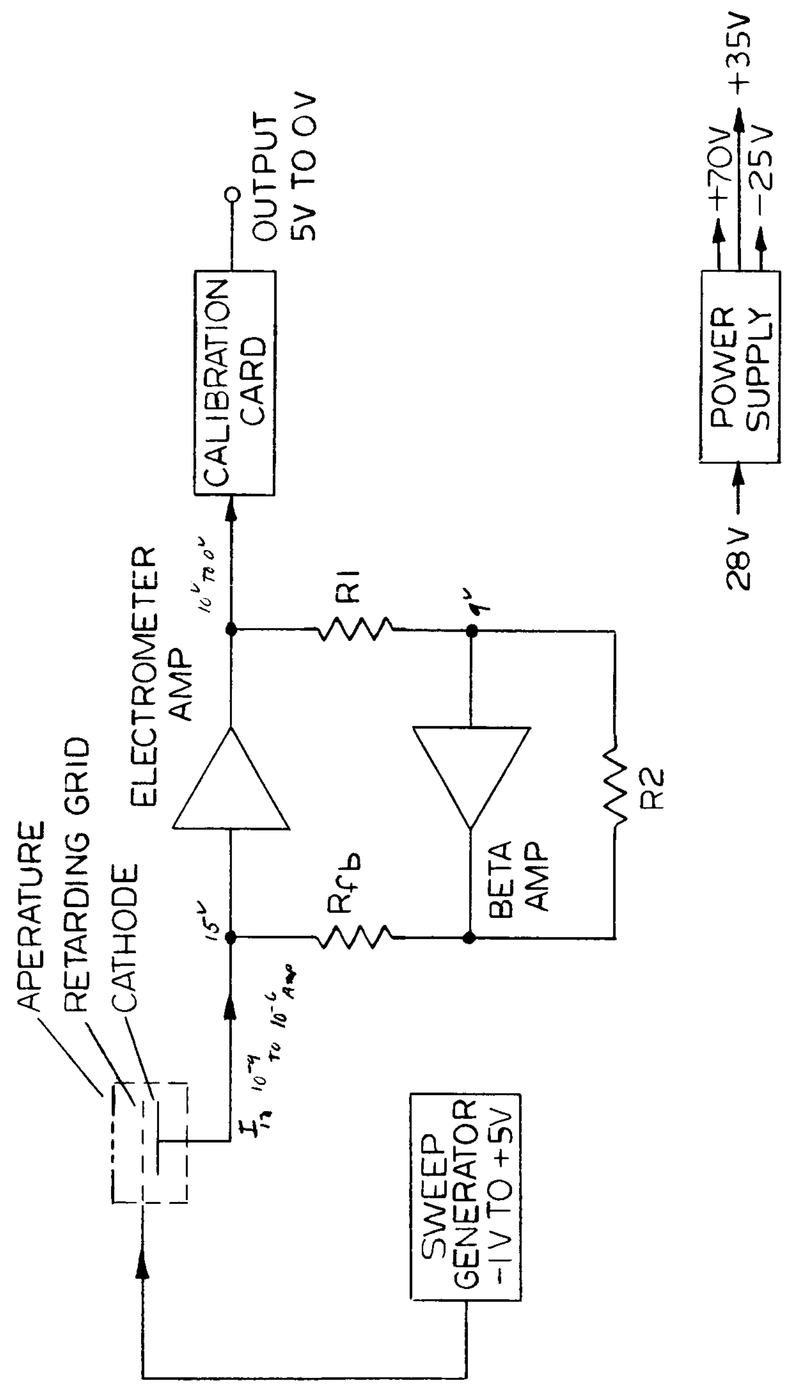


Figure 4.2 Retarding Potential Analyzer Block Diagram

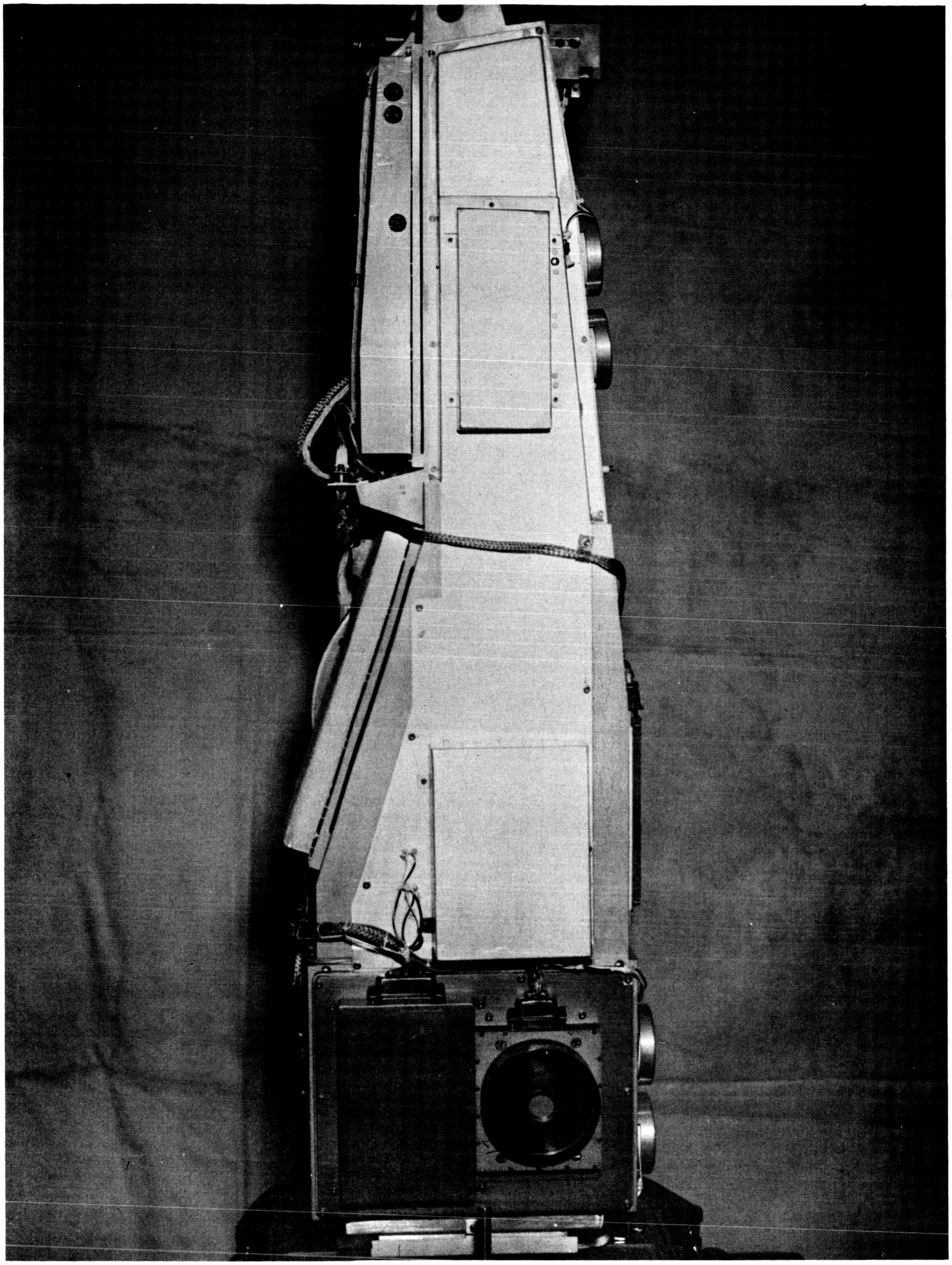


Figure 4.3 Retarding Potential Analyzer Mounted
on Rocket Monochromator

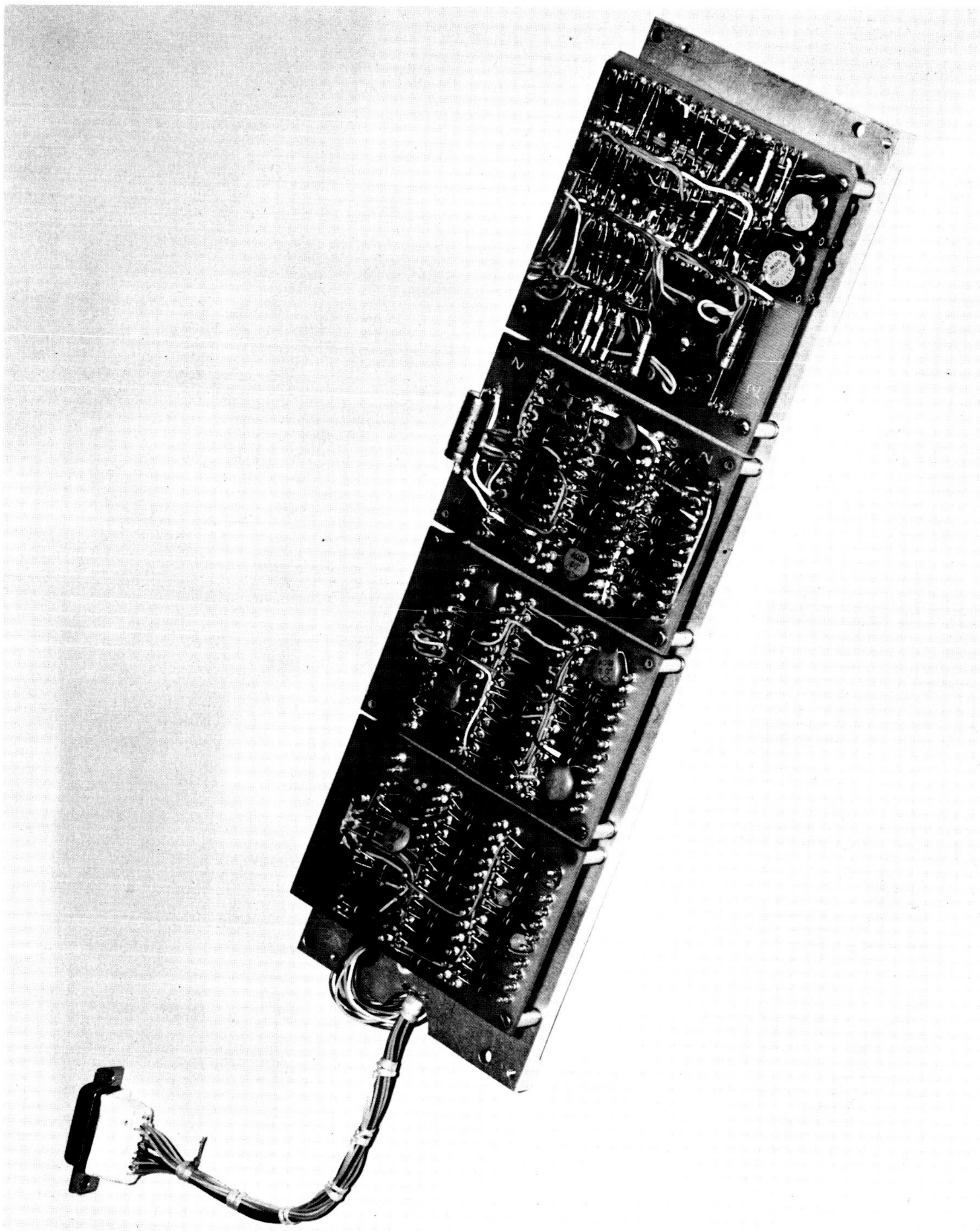


Figure 4.4 RPA Electronics

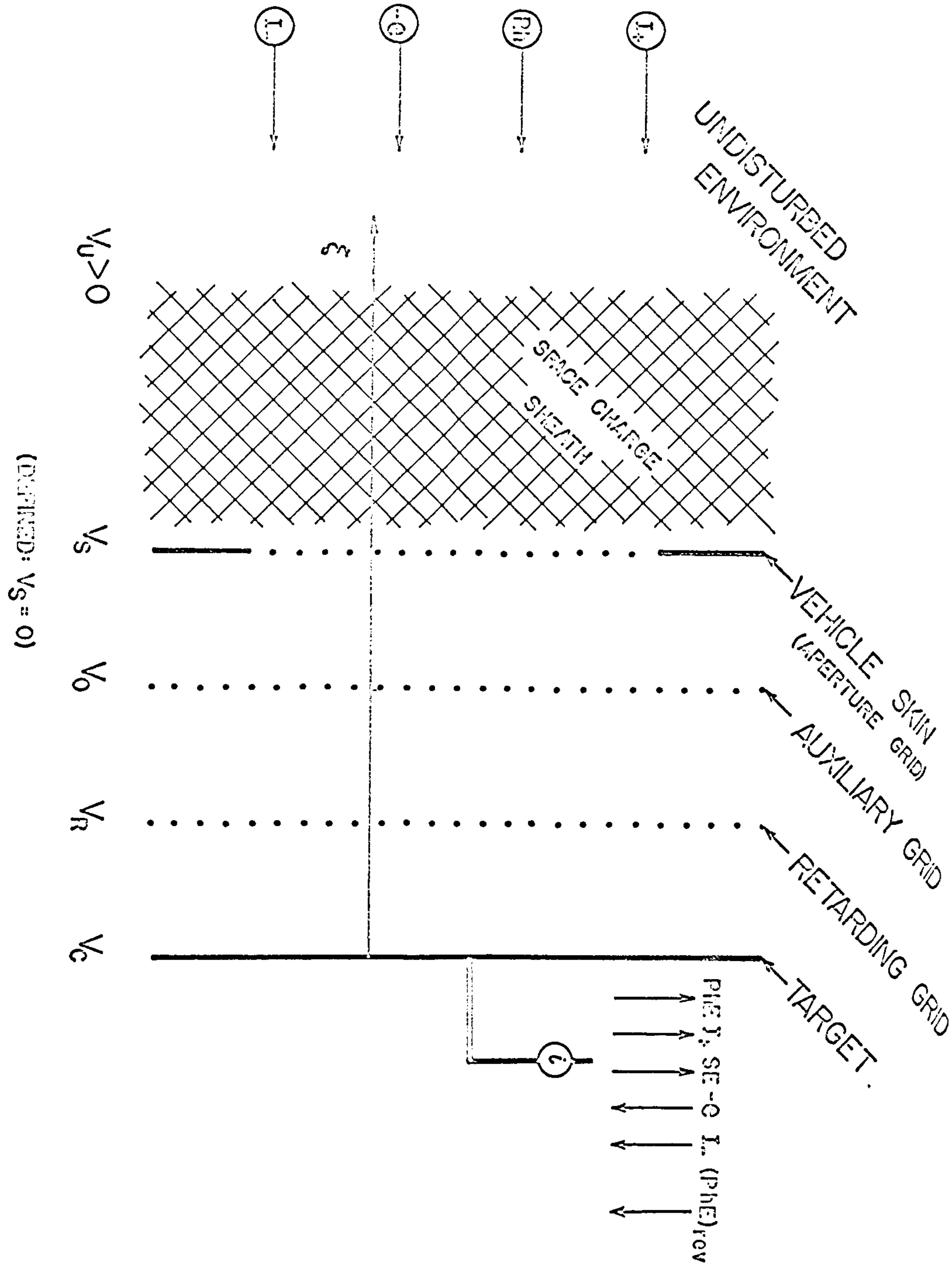


Figure 4.5 RPA Detector Schematic

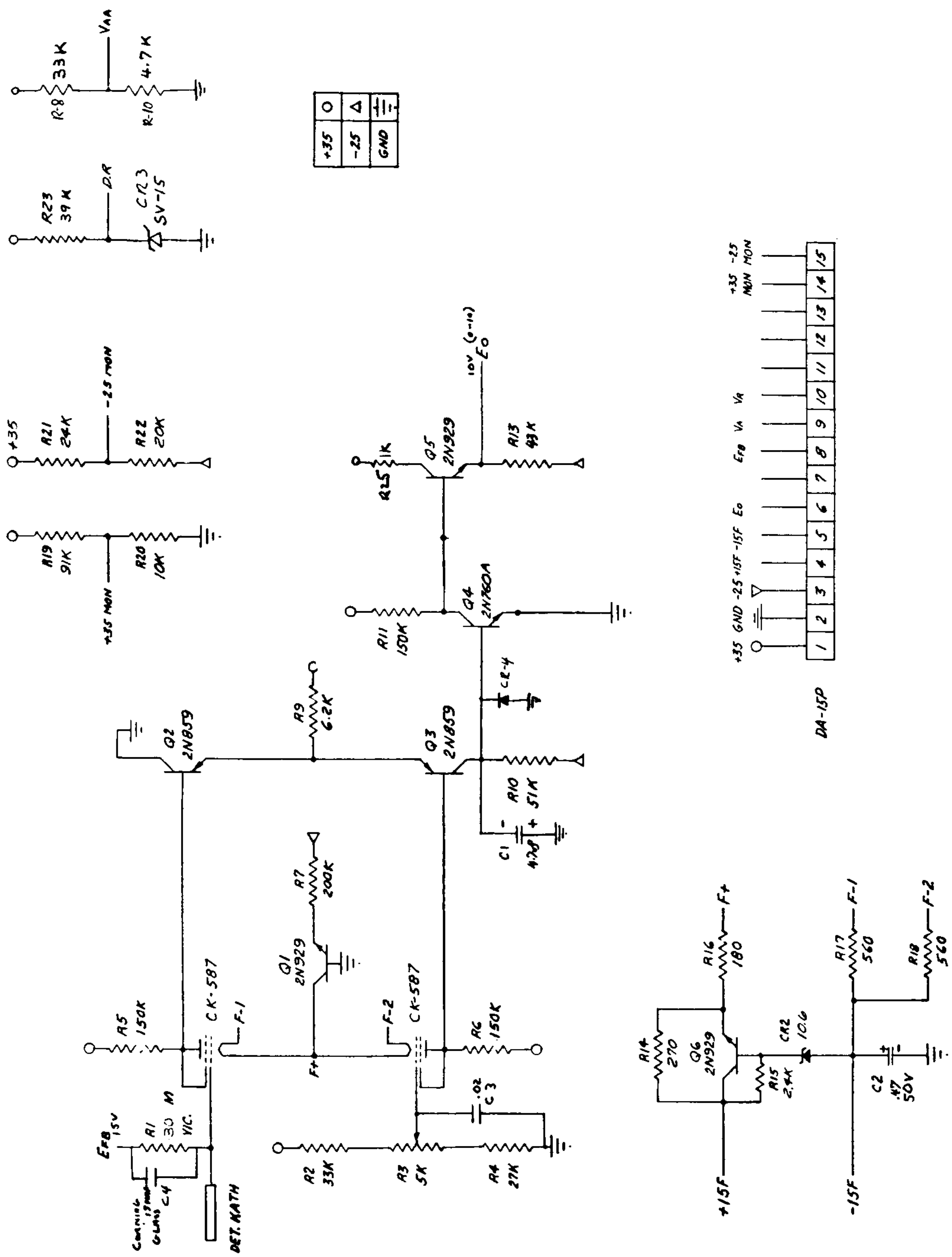


Figure 4.6 Schematic - Electrometer Amplifier RPA Monochromator Aerobee

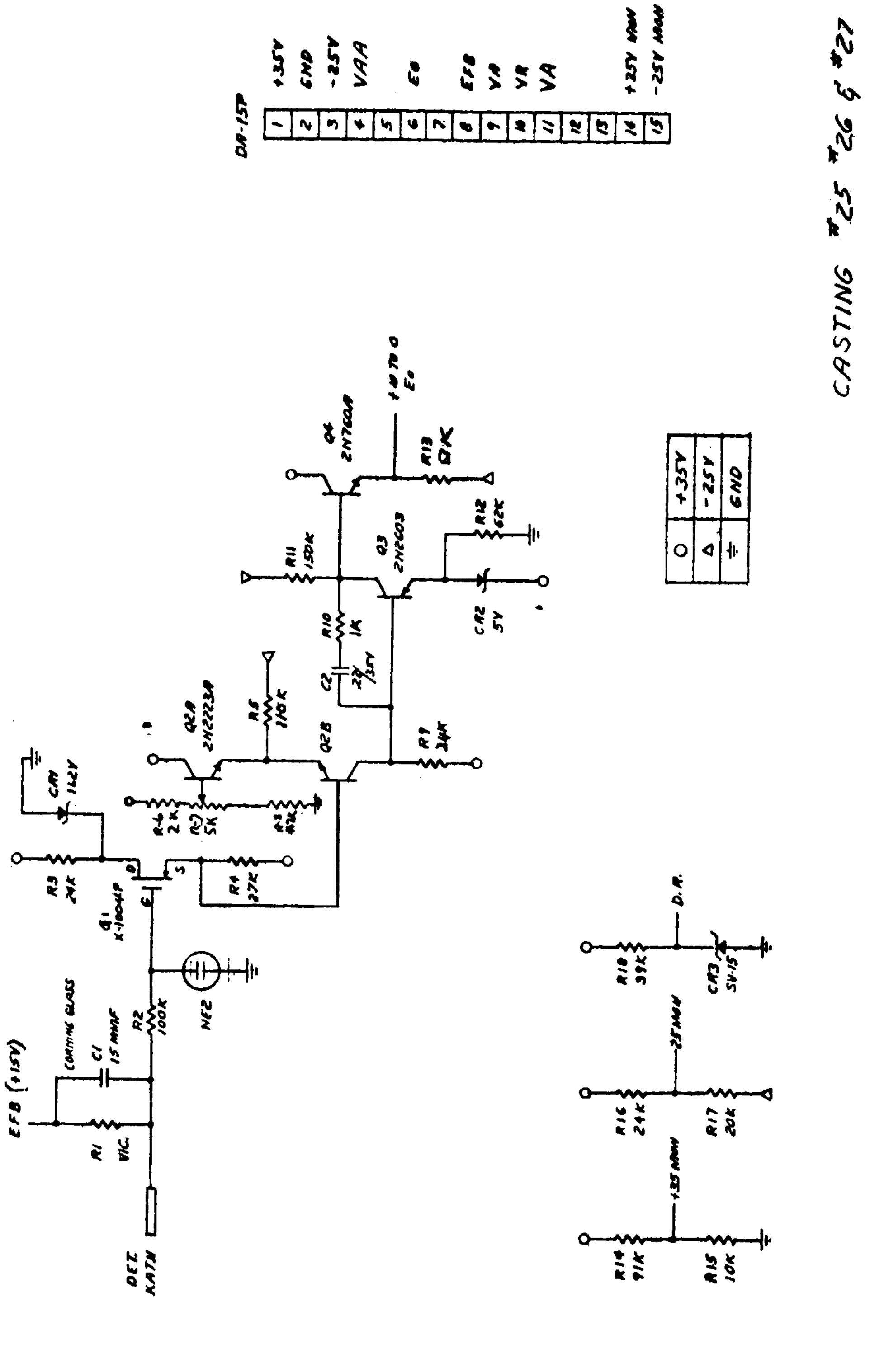
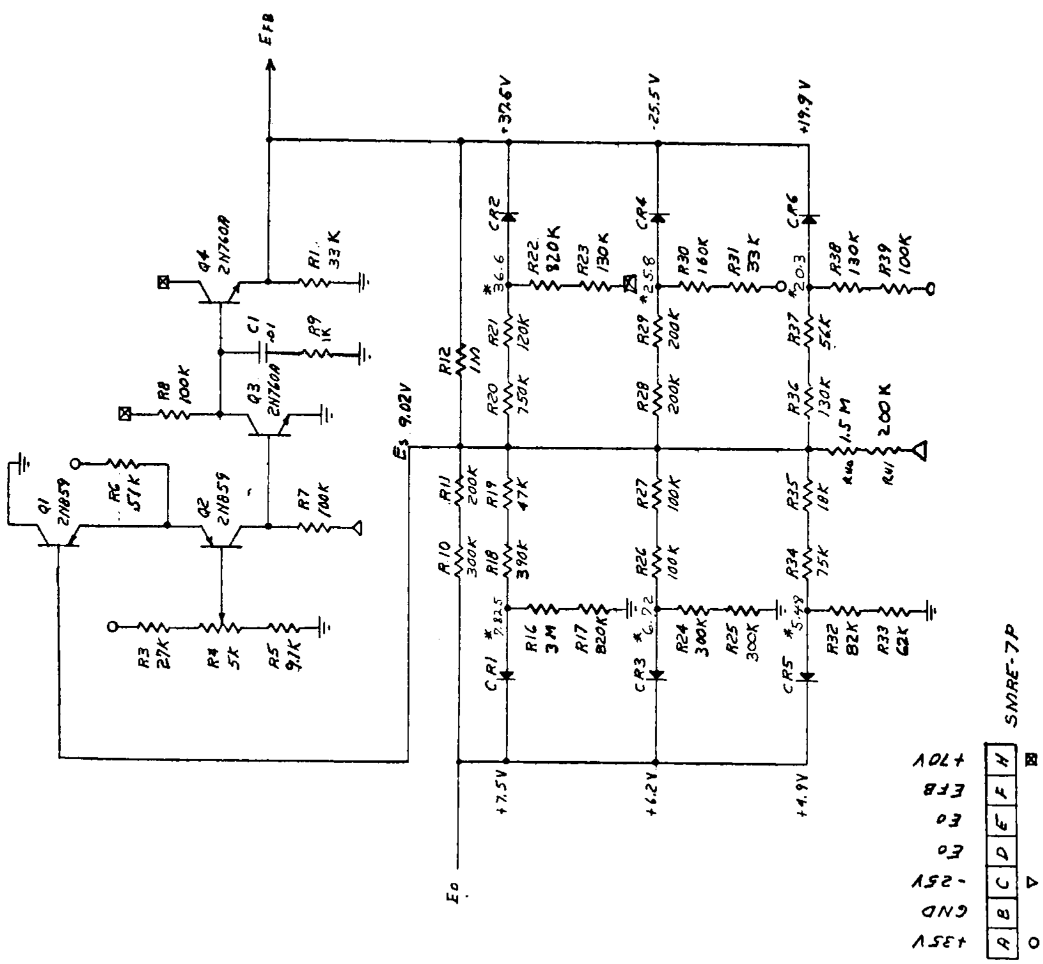


Figure 4.7 Schematic - Electrometer Amplifier RPA
Rocket Monochromator Aerobee



Eo		EFB		B AMP GAIN
Eoo	+10V	EFB0	+15V	
Eo1	+7.5V *	EFB1	+15.5V	.2
Eo2	+6.2V *	EFB2	+16.06V	.43
Eo3	+4.9V *	EFB3	+17.26V	.924
EoM	4.25	EFBM	+18.56V	2
Eo4	+3.6V	EFB4	+19.86V *	
Eo5	+2.3V	EFB5	+25.46V *	4.3
Eo6	+1.0V	EFB6	+37.36V *	9.24
EoFS	0	EFB FS	+57.36V	20

Note Set E_s to 9.02V @ E_{oM} 4.25V

* Break voltages set with digital

Figure 4.8 Schematic - B-Amp. Card RPA Monochromator Aerobee

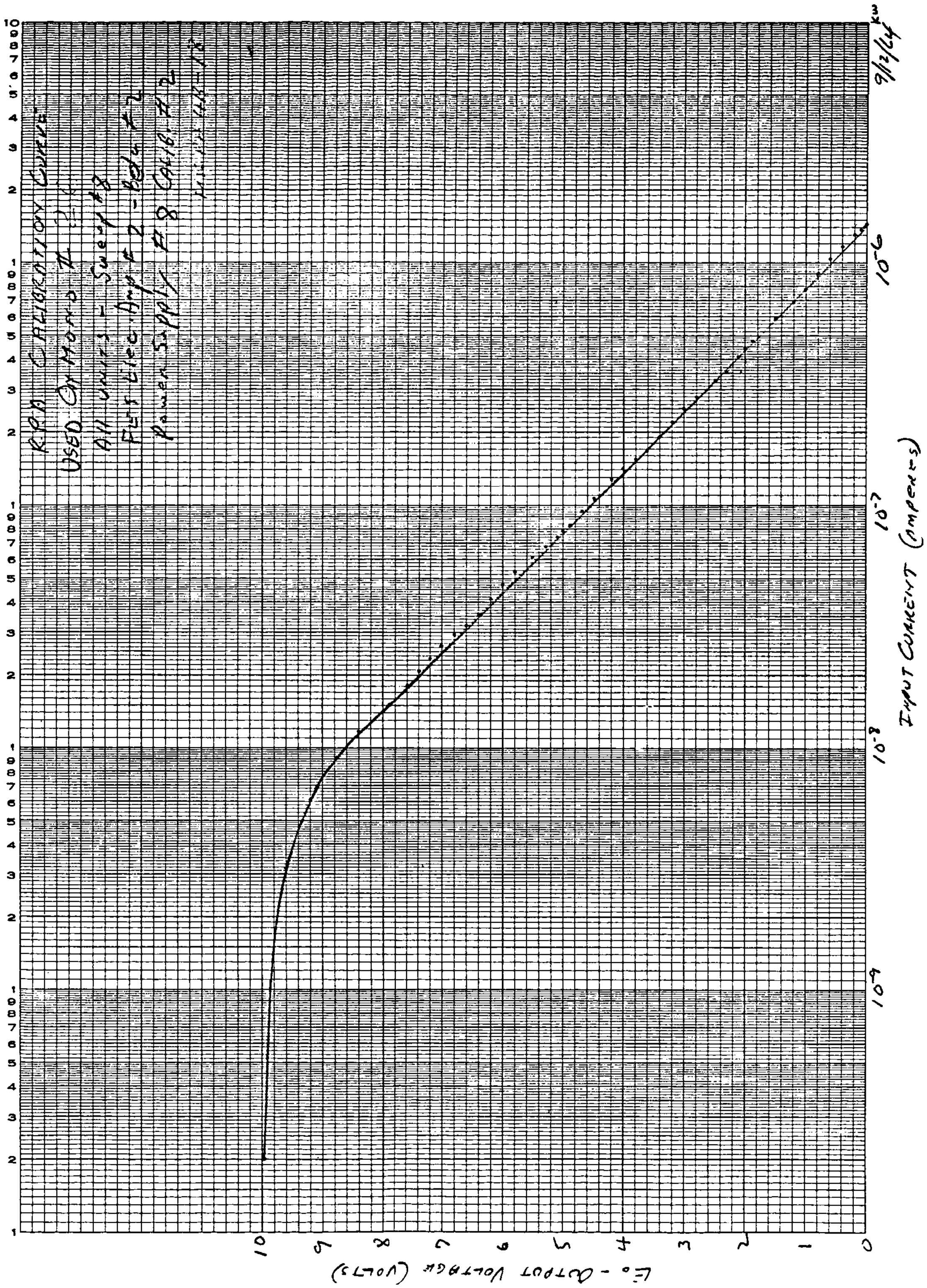


Figure 4.9 RPA Calibration Curve

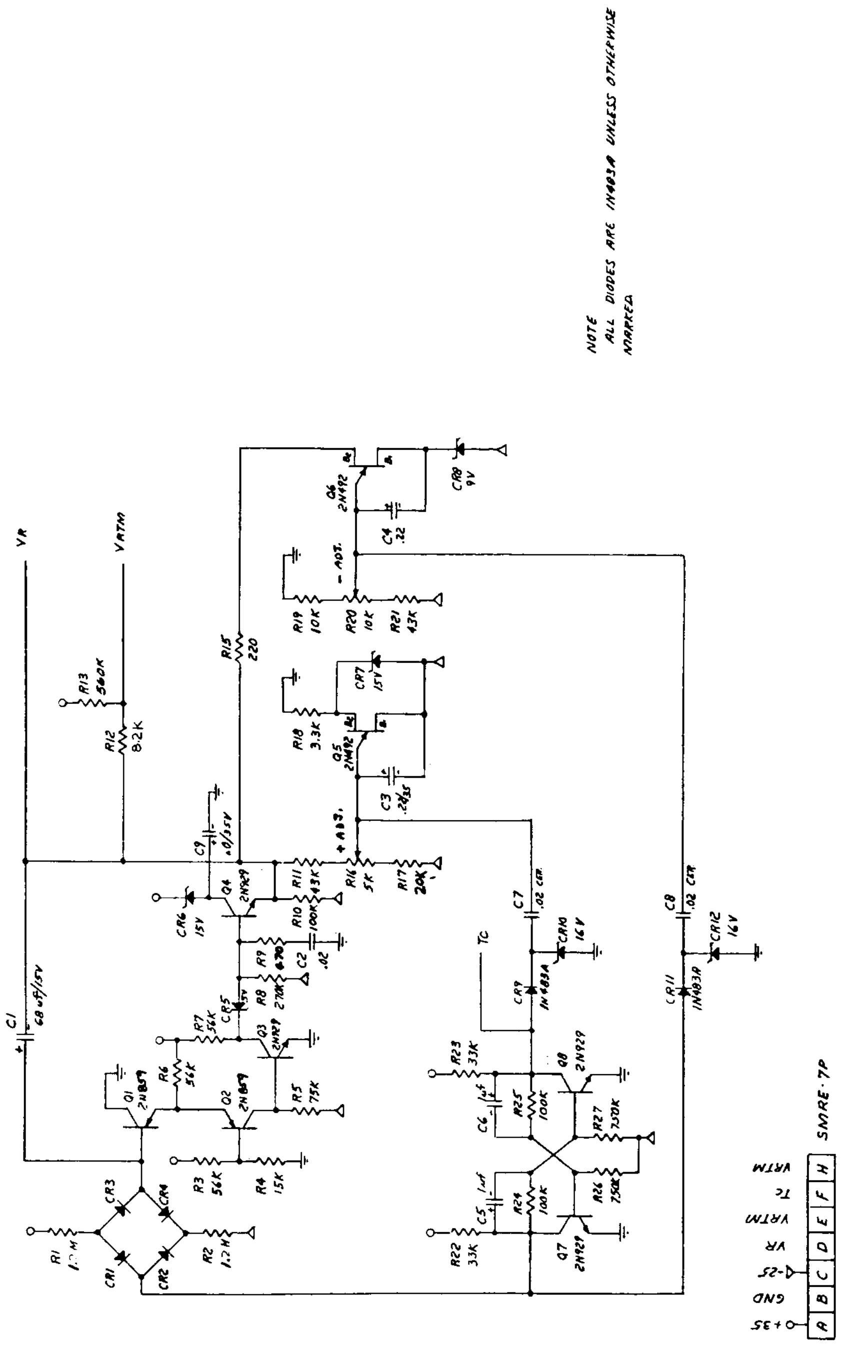


Figure 4.10 Schematic - V_R Sweep Generator RPA Monochromator Aerobee

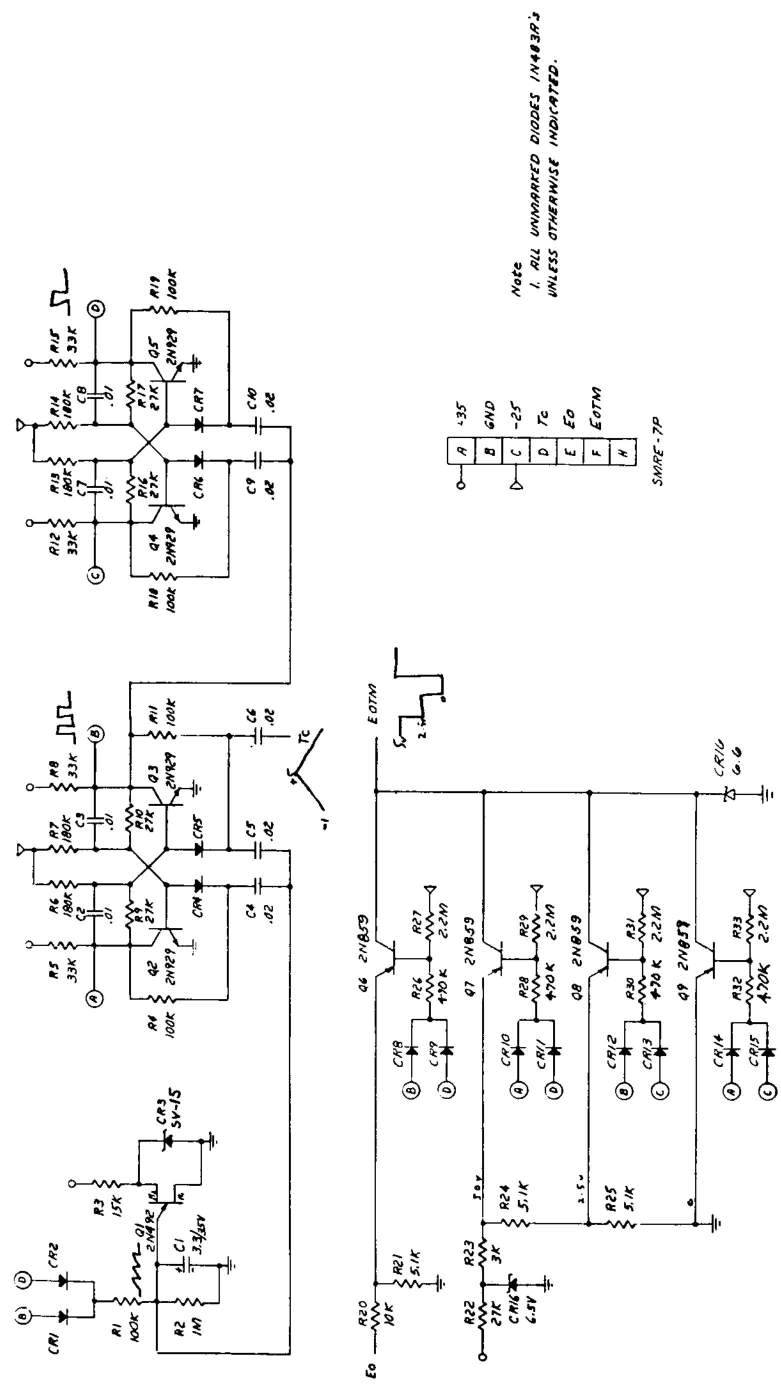


Figure 4.11 Schematic - Calibration Card RPA Mono-
chromator Aerobee

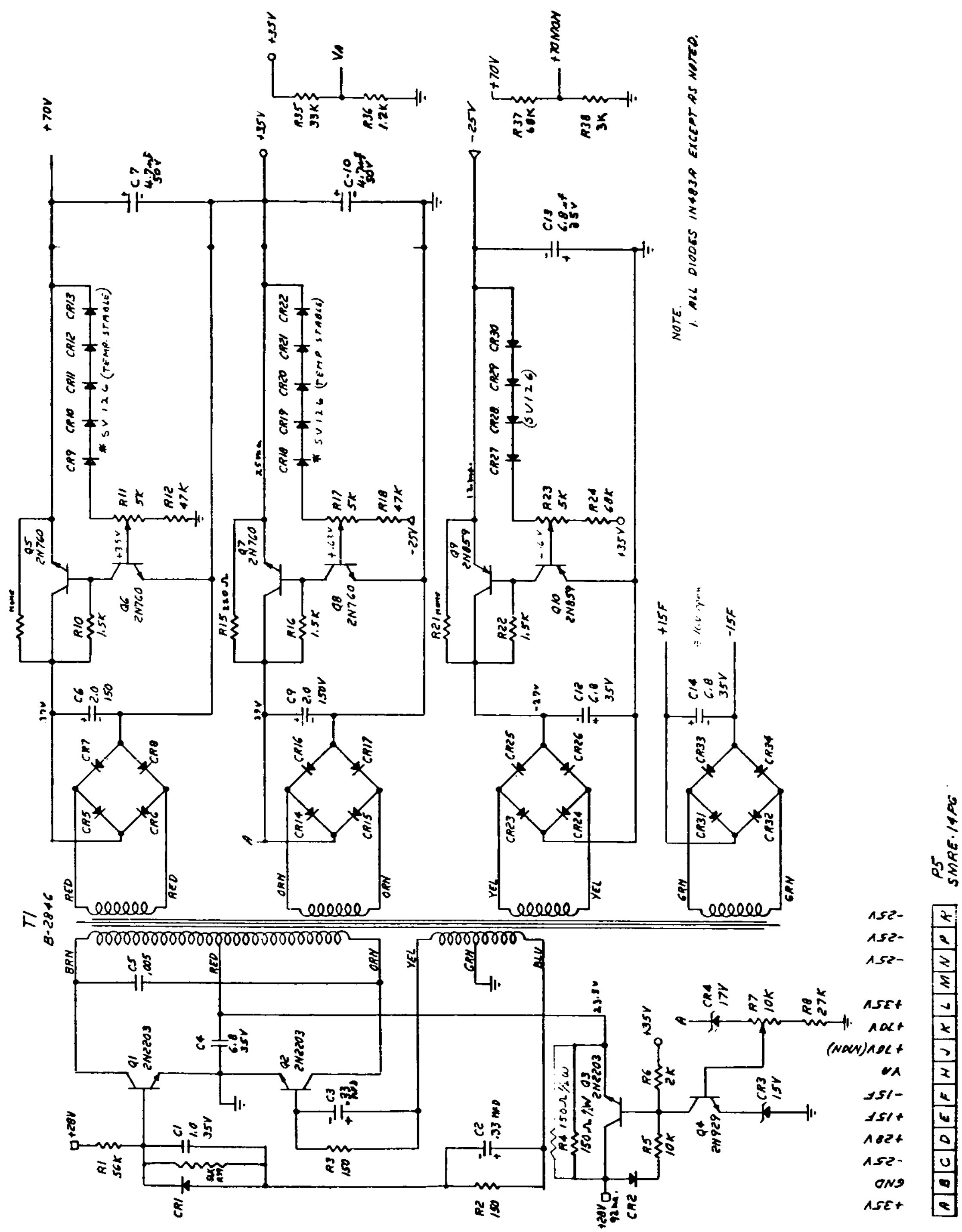


Figure 4.12 Schematic - Power Supply Program Unit RPA Monochromator Aerobee

5. PROPORTIONAL COUNTER SPECTROMETER

CONTENTS

5. PROPORTIONAL COUNTER SPECTROMETER

5.1 Introduction

A proportional counter detector was used with a linear amplifier and pulse height analyzer to measure the X-ray photon flux from the sun during flight through and above the region of significant atmospheric absorption. The counter was sensitive to the range of wavelengths from 0.8 Angstroms to 12 Angstroms. Pulse height analysis was achieved by a 3 or a 5 step attenuator at the output of the linear amplifier, followed by a fixed bias discriminator and a scaler. This electronics was built by Adcole Corporation.

The initial instrument was designed to be carried aloft on the rocket monochromator described in Section 1 of this report. The detector is oriented on the monochromator casting so that it points at the sun when the monochromator instrument is pointed at the sun by the biaxial solar pointing control built by Ball Brothers Research Corporation of Boulder, Colorado.

During the period covered in this report, two instruments were flown from White Sands, New Mexico on Rocket Monochromators #17 and #19 launched May 2, 1963 and December 12, 1963. A different package was also designed for flight on Black Brant vehicles from Fort Churchill, Canada. Two of these packages were built and one was successfully flown in October 1964.

A block diagram of a typical system is shown in Figure 5.1.

5.2 Description

The electronics of the two packages mentioned above are very similar. The Black Brant system was expected to encounter higher intensity, so an extra count-down of 4 was inserted ahead of the 32 step staircase generator. The threshold sequencer is also different in the two systems, as one drove a 3 step attenuator and the other a 5 step attenuator.

5.2.1 Proportional Counter

The proportional counter detector itself was designed by J.E. Manson of AFCRL and constructed by Comstock and Wescott, Inc. The counter requires a stable 1800 volt power supply for its operation. These supplies were obtained from Matrix Corporation and also from Electronic Development Corporation. The supplies themselves are unregulated but produce a constant output when supplied by a regulated voltage and feeding a constant load. The Matrix supplies are regulated, adjustable from 1700 to 2200 volts, and well filtered.

5.2.2 Pulse Amplifier

The pulse amplifier is similar to the amplifier used on the rocket monochromator. A better noise figure is required and this was achieved with 2N917 transistors. The gain is adjustable but must be constant after adjustment. Also a positive pulse is required to activate the Schmitt trigger. This schematic is shown in Figure 5.2.

5.2.3 Pulse Height Discriminator

The pulse height discriminator is a step attenuator followed by a stable-threshold Schmitt trigger. The attenuator is a resistor divider. Relays switch the output from tap to tap. The relays are controlled by the threshold sequencer. The Schmitt trigger drives a 32 step staircase generator consisting of five binary stages which is similar to the counter boards used in the rocket monochromators. A schematic is given in Figure 5.3.

5.2.4 Threshold Sequencer

The threshold sequencer controls the relays which produce the attenuator stepping action. Each attenuator step is sampled for about 1.5 seconds. The sequencer circuitry also produces signals to activate solenoids which insert shutters and a calibration source in front of the detector. A schematic is shown in Figure 5.4.

5.2.5 Power Supply

The low voltage power supply is a series regulator giving +18 volts from the 28 volt battery and also a converter driven from the regulated 18 volt output to give -20 volts. A schematic is given in Figure 5.5.

5.3 Flight Operations

5.3.1 Aerobee Vehicle at White Sands, New Mexico

Two experiments were flown at White Sands, New Mexico. The first, on 2 May 1963, contained five thresholds, each sampled for 1.5 seconds so that each complete frame took 7.5 seconds. On alternate frames a calibration radioactive source was inserted in front of the detector. Thus, calibration of the experiment was obtained during flight. A picture of the package on the side of the monochromator is given in Figure 5.6. Good data was obtained.

The second experiment was flown on 12 December 1963. This had only 3 different attenuator steps, effectively separating the wavelength measured to less than 10 Å, less than 5 Å, and less than 2 Å. This experiment also yielded data.

To check out the experiment during calibration in the laboratory and prior to launch on the vehicle, a special console was designed and fabricated. A photograph is shown in Figure 5.7.

5.3.2 Black Brant at Fort Churchill

Two proportional counter systems were fabricated for use on the Black Brant vehicle. The circuitry was very similar to that of the units used on the monochromators. Again three thresholds were used per frame, but both a shutter and calibration source were inserted as follows: Frame 1, data only; Frame 2, data plus calibration; Frame 3, data only; Frame 4, shutter closed, no data, no calibration; Frame 5, same as Frame 1, etc. Two views of the electronics are given in Figures 5.8 and 5.9.

This experiment was launched at Fort Churchill, Canada, during an aurora. A high count rate was expected so an extra "divide by 4" was inserted ahead of the staircase generator. A high count was obtained corresponding to 65000 counts per second at some wavelengths.

A special console was also constructed for use with this package.

5.4 Data Reduction

Data reduction on the proportional counter experiments was initially done by hand. The count rate during each threshold was read from the telemetry paper records.

Recently, automatic techniques were applied to the reduction. The same data reducer used with the monochromator was used to produce plots of counts per 0.4 second sample versus wavelength. The automatic reduction was very successful.

5.5 List of Figures

Figure

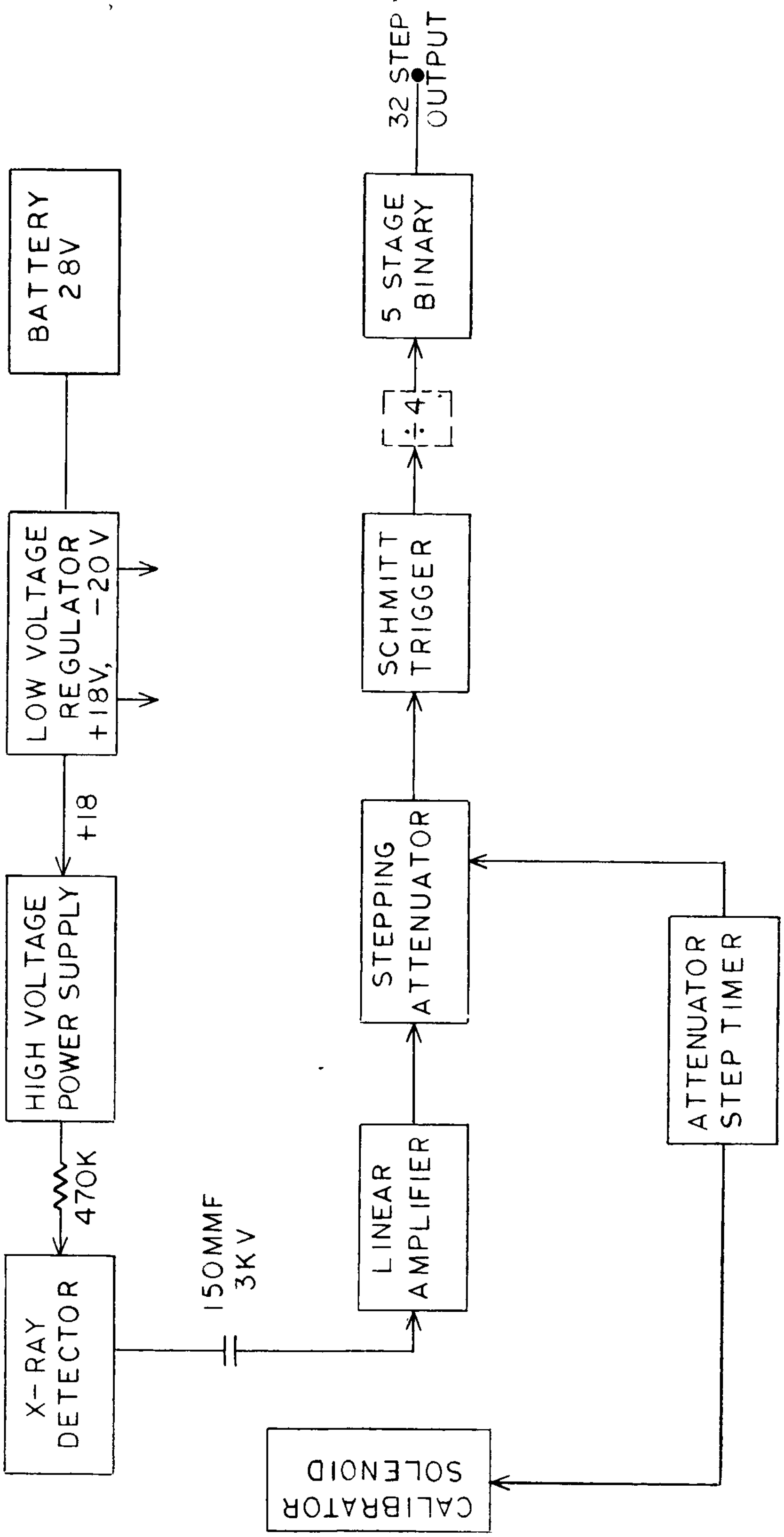


Figure 5.1 Proportional Counter System Block Diagram

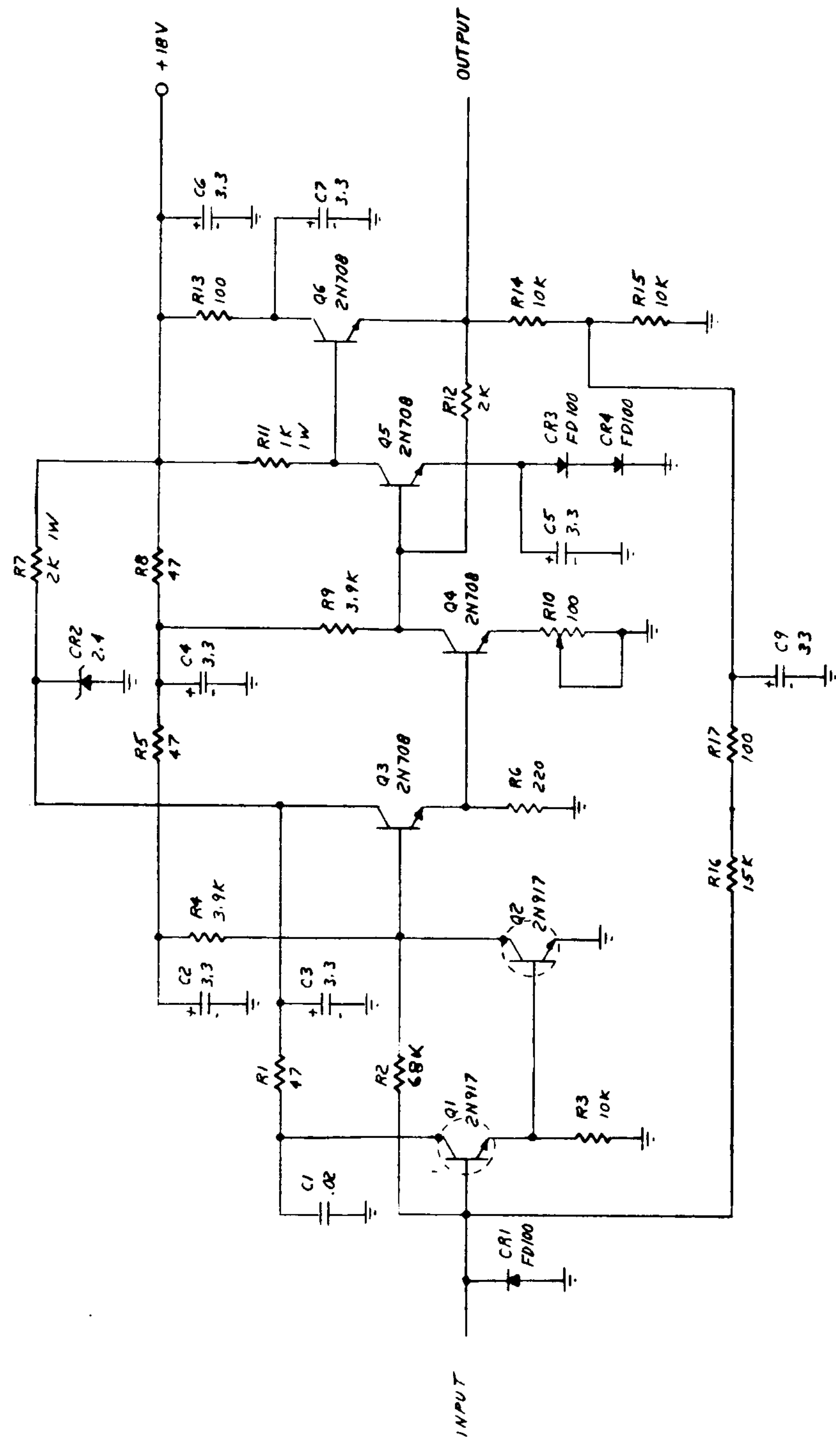


Figure 5.2 Schematic - Pulse Amplifier Proportional Counter

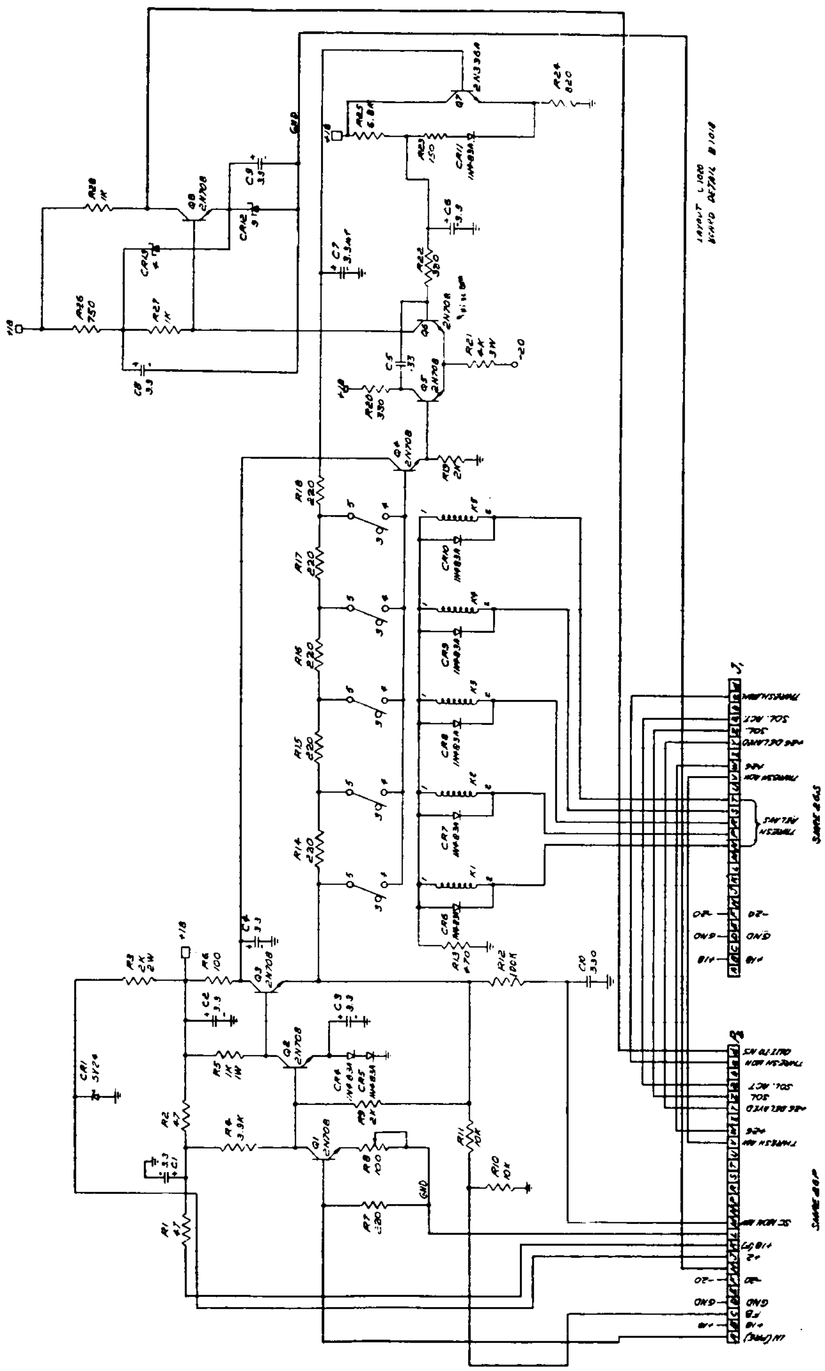


Figure 5.3 Schematic - Amplifier and Pulse Height Discriminator

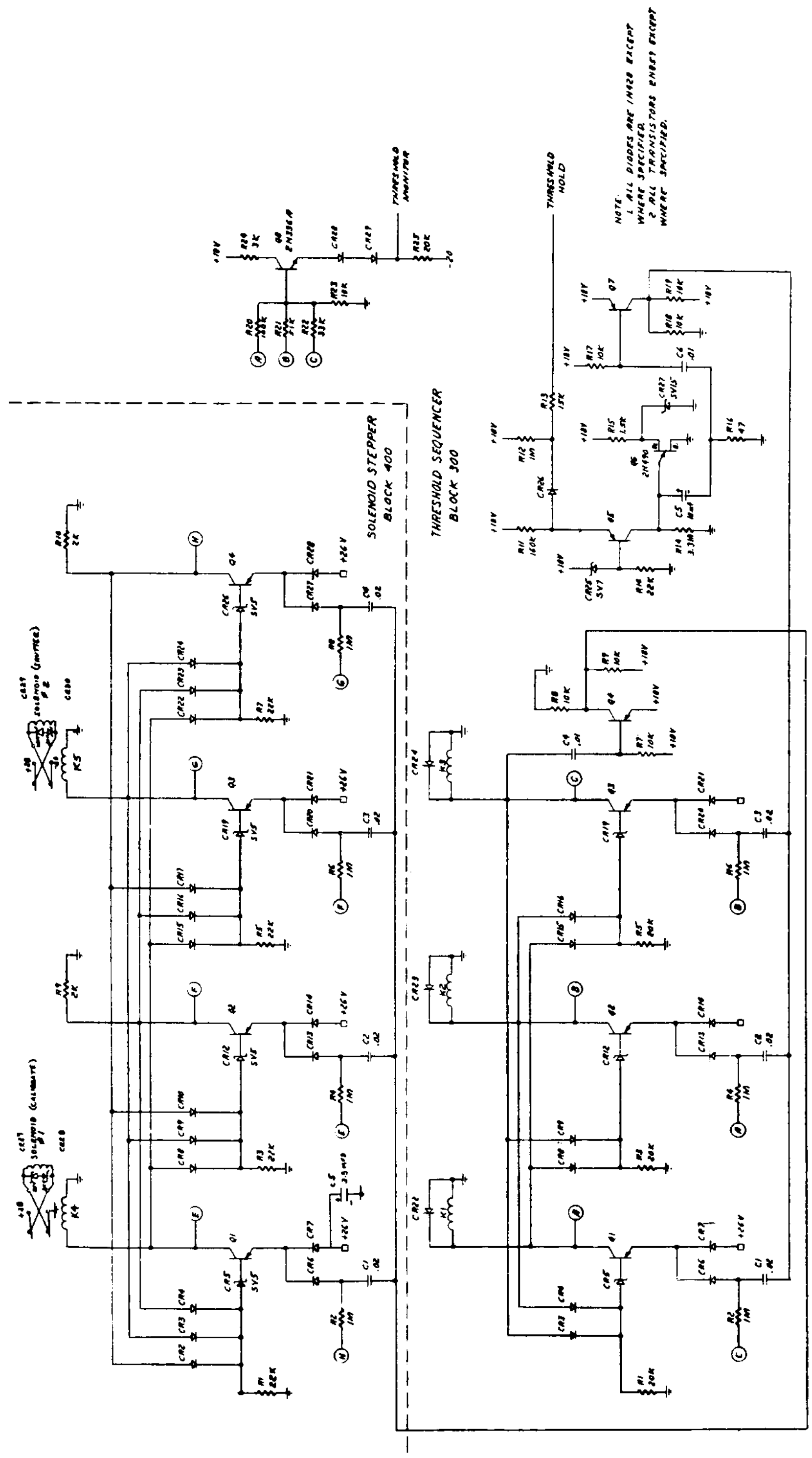


Figure 5.4 Schematic - Solenoid Stepper Threshold Sequencer

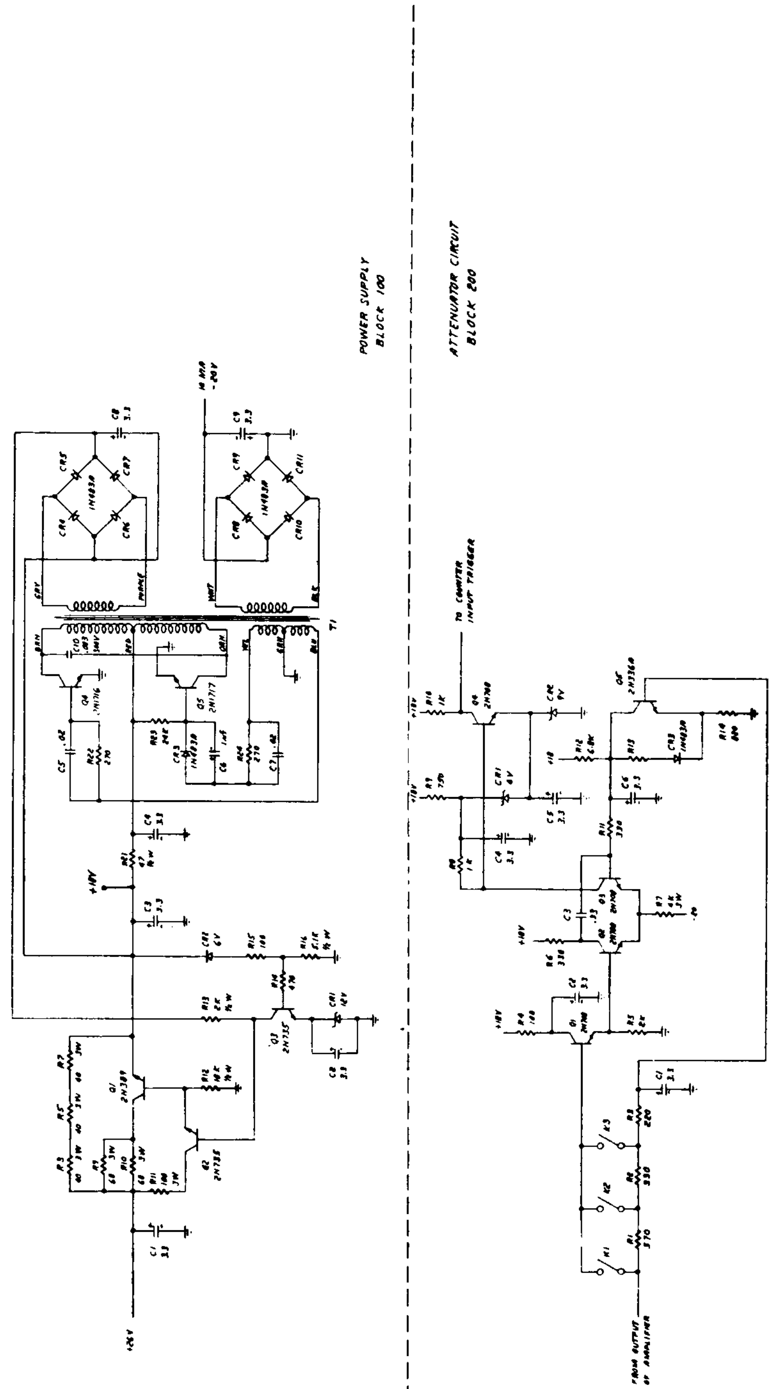


Figure 5.5 Schematic - Power Supply Attenuator Circuit

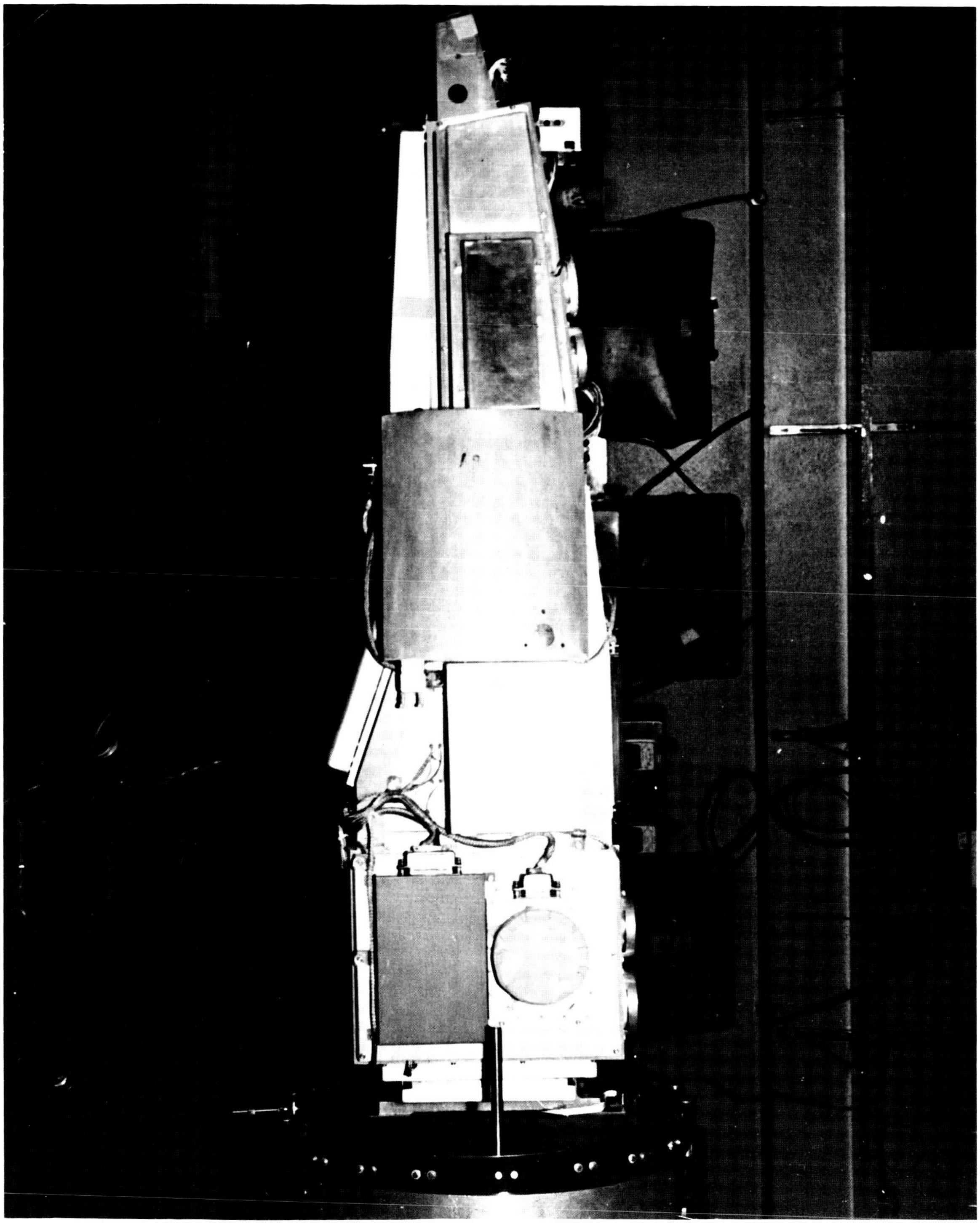


Figure 5.6 Proportional Counter on Rocket Monochromator

Figure 5.7 Proportional Counter Console

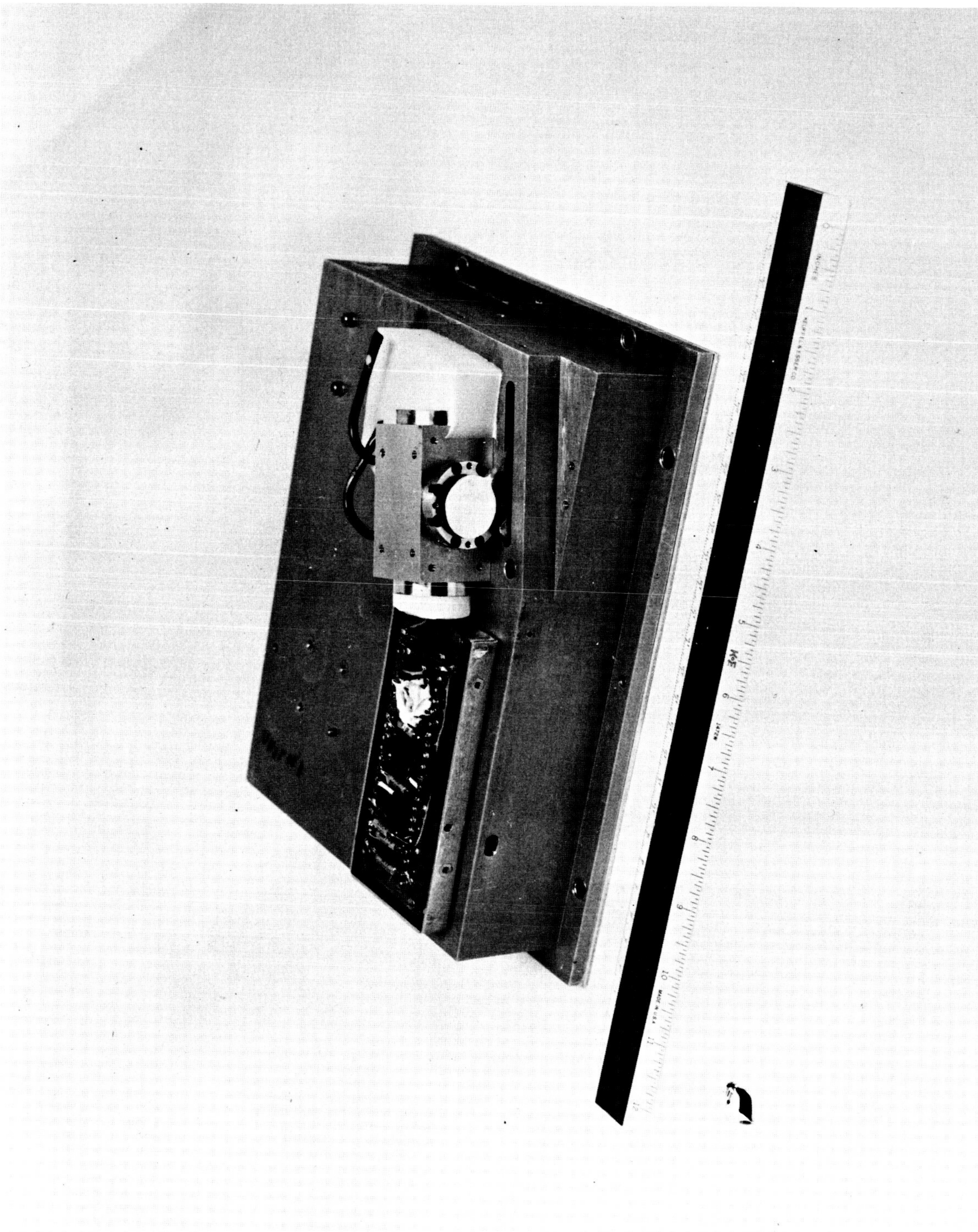


Figure 5.8 Proportional Counter Electronics

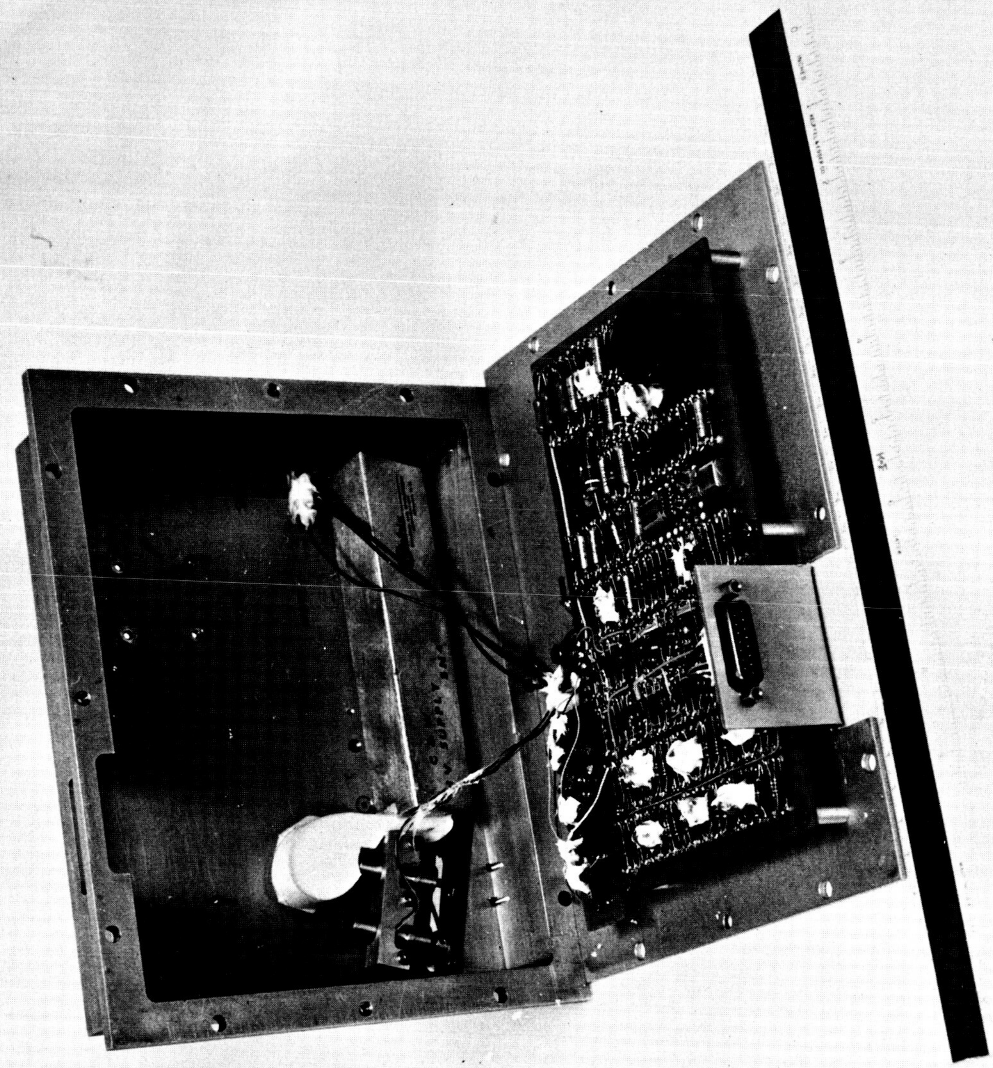


Figure 5.9 Proportional Counter Electronics - Cover Open

CONCLUSIONS

The results achieved under this contract have contributed greatly to the knowledge of the upper atmosphere. Adcole Corporation's task was to provide the electronics to implement the experiments devised by the Solar Ultraviolet Branch at AFCRL. This task was completed successfully. The work continues under contract AF 19(628)-5042 and some of the equipment developed under this contract, especially the satellite experiments, will be launched in 1965 under the new contract.

In the performance of Adcole Corporation's contract the following tasks were completed:

Nine rocket monochromators were equipped with electronics. Five of these were flown on Aerobee-150 vehicles and four were successful.

Three satellite monochromator electronic systems were built for the OSO-C and D satellites, with launches scheduled in 1965 and 1966.

Four satellite monochromator electronic systems were built for the OGO-C and D satellites, with launches scheduled in 1965 and 1966.

Five retarding potential analyzers were built and flown on rocket monochromators. All gave data except one, which apparently had a faulty detector.

Four proportional counter experiments were fabricated. Three of these have been flown and gave data. The fourth is scheduled for a 1965 flight .

Assistance was given by Adcole in the field operations associated with the rocket flights and in the integration of the satellite experiments on the spacecraft. This required the design and fabrication of nine test consoles.

Data reduction has been accomplished on the monochromator experiments and proportional counter experiments with the equipment built by Adcole for that purpose. Also hand reduction of retarding potential analyzer data was done by Adcole Corporation.

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5. AUTHOR(S) *(Last name, first name, initial)*

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13. ABSTRACT This report describes the design, construction, test and flight use of the electronic portions of research instruments used on rockets and satellites for the investigation of ultraviolet solar radiation. These instruments include grating monochromators for measurements in the 55 - 1300 Angstrom range and proportional counter spectrometers in the 1 - 10 Angstrom range. Also described is work done on retarding potential analyzers used for analysis of environmental charged particles, including measurement of electron temperature. All the instruments are of a telemetering type. Associated equipment used for calibration and testing of the instruments in both the laboratory and the launch phases is described. Automatic data reduction equipment was developed and used successfully. Experiments involved OSO, OGO and Air Force satellites and Aerobee-150 and Black Brant rockets.

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